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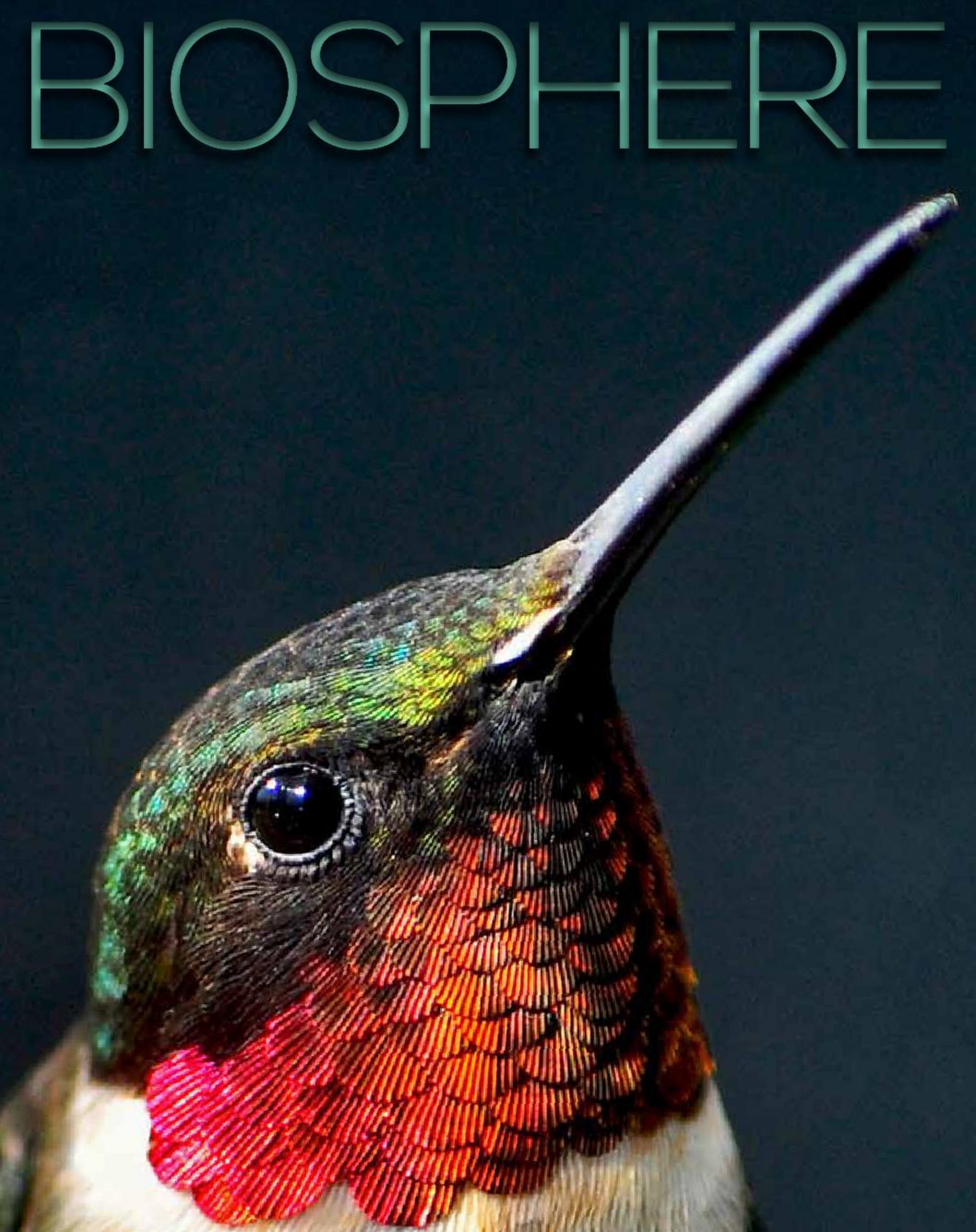

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We have endeavoured to select a representation across topics, and scientific integrity is of the utmost importance. We welcome your feedback and responses to the articles published here. With your permission, these may form part of a Conversation section in the next issue.

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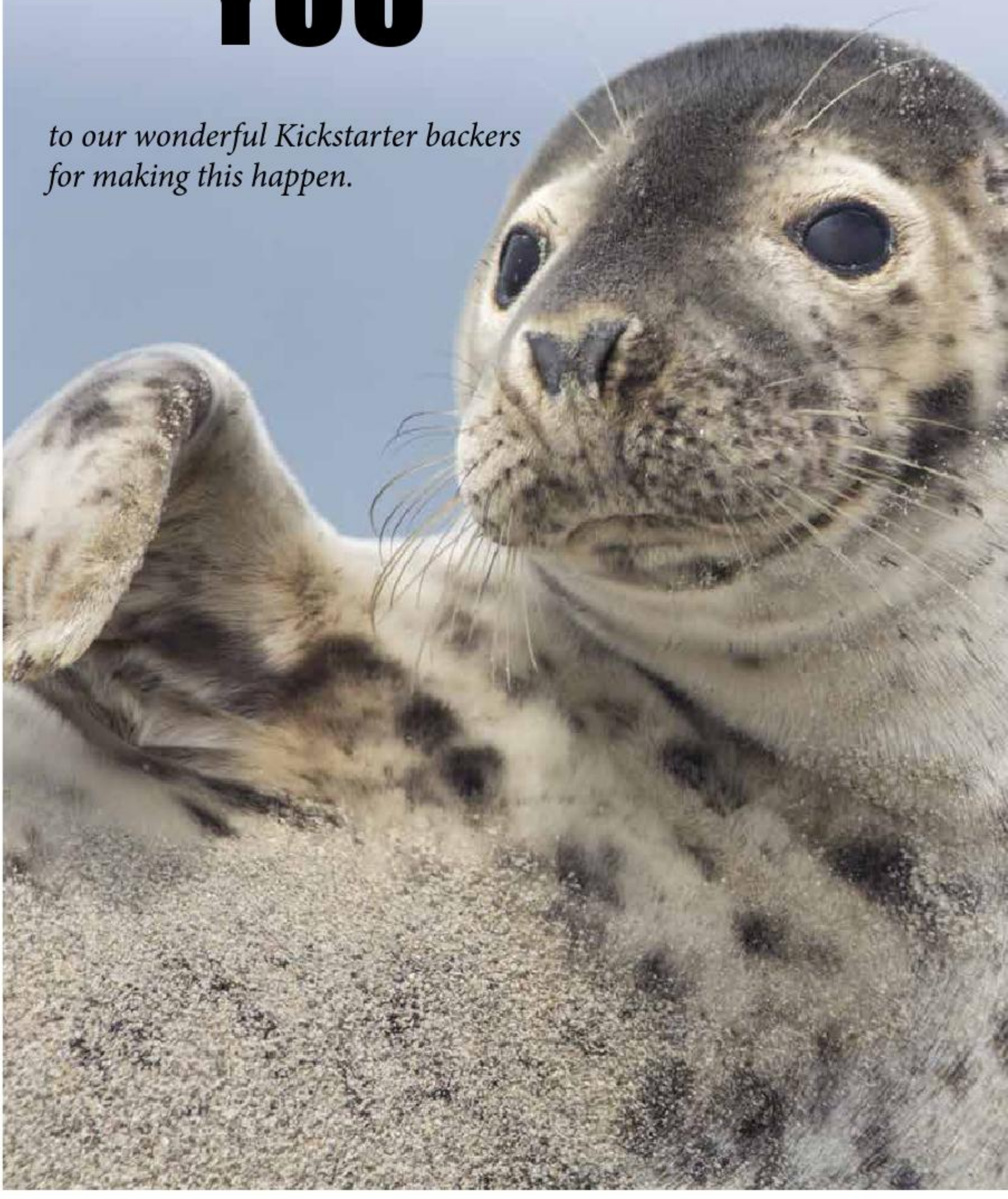

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Sailing by, Matthew Smith

The Wildlife Photographer of the Year competition, run by the Natural History Museum, is celebrating its 50th year of discovering amazing photography. This Portugese man of war, a finalist in the invertebrate category, was taken off the coast of New South Wales, Australia. Despite wearing a wetsuit, the production of this piece of art did not allow Matthew to escape without being stung. This year's 100 award-winning images will embark on an international tour beginning in October.
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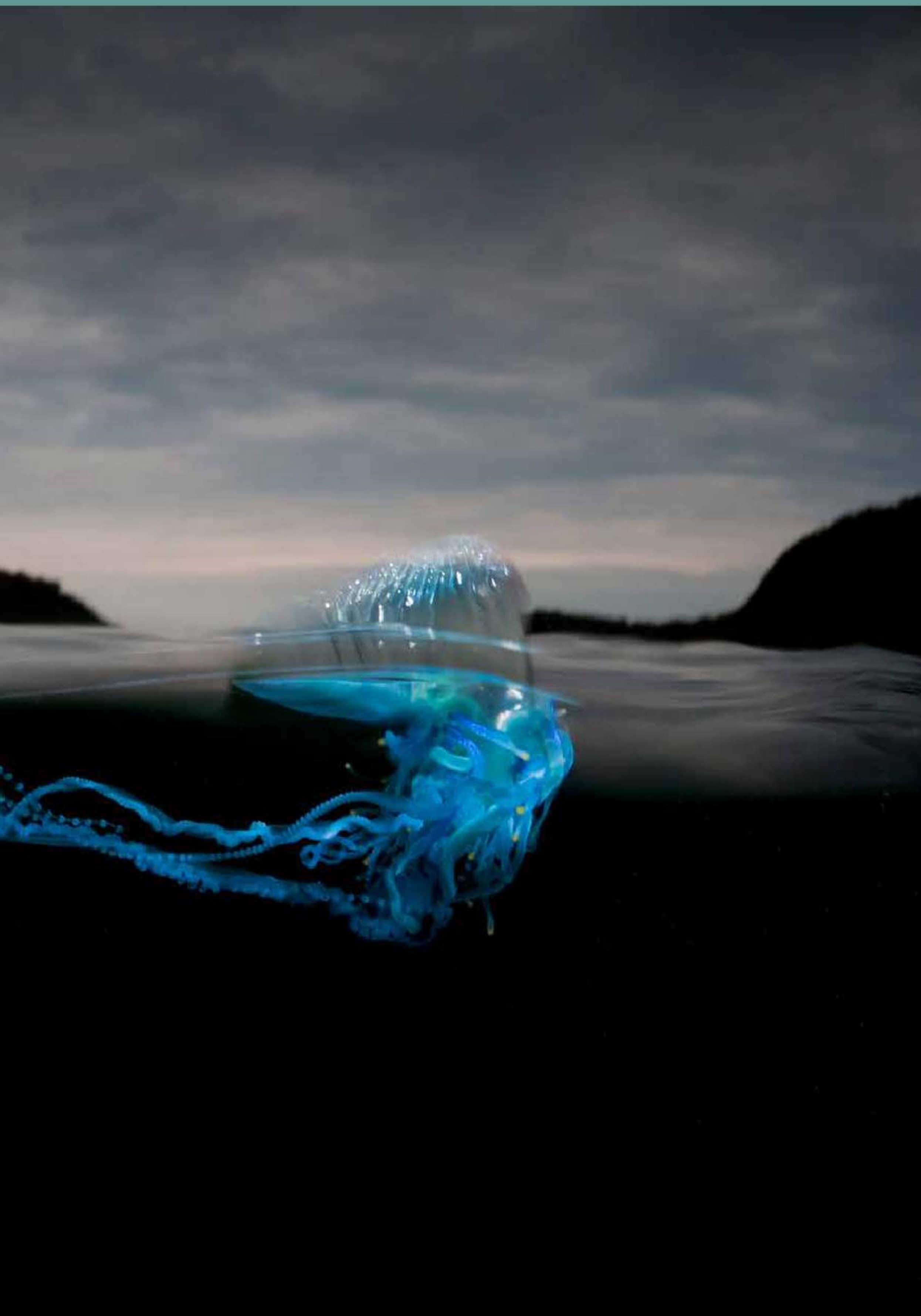

ECOLOGY in BRIEF

Touching interactions

Simple touch could be a vital factor in establishing symbiosis between plants and fungi.

Mechanical stimulations are essential in a plant's everyday existence. They provide cues that plants perceive and respond to, and can include wind, gravity, pathogens and damage. Touch, too, is a mechanical stimulation. New research has discovered the importance of that first microbial touch between plant, fungi, and bacteria. There is growing evidence that mechanical stimulation will be sent by symbionts to indicate their presence, with the researchers suggesting it can be akin to politely knocking on the door and awaiting a response to begin mutually-beneficial symbiosis.

Mycorrhizae are one example of beneficial fungi that will communicate with plants in this way, before symbiosis helps the plant absorb essential nutrients from its environment. Bacteria too use touch to initiate symbiosis. Rhizobia is a bacteria that appears to make nitrogren from the atmosphere more readily available to a plant it is engaged with. The study discovered that mechanical stimulation is once again heavily involved: when rhizobia first come into contact with a plant's root hair, the bacterium will be trapped as the hair curls around it. This entrapment signals the plant to accommodate the rhizobia, and the mutually beneficial symbiosis begins.

Understanding these interactions and mechanical stimulations could aid in the cultivation of associations with beneficial microbes, as well as defences against harmful pathogens.

Jayaraman, D, Gilroy, S & Ane, J-M. (2014). Staying in touch: mechanical signals in plant-microbe interactions. Current Opinion on *Plant Biology*, 20, 104-109.

Invasive cascade

Evidence of an invasive species of grass negatively impacting on a native population has been uncovered by researchers from the University of Georgia. In a complex interaction, invasive Japanese stilt grass was found to be affecting American toad populations wherever it spreads. The cause is increased predation: the researchers discovered that wolf spiders are thriving in the habitat created by stilt grass, and with their population increasing, toads are experiencing higher predation pressure. The unpredictable nature of how invasive species may affect an established ecosystem is highlighted by the spider population boom and subsequent fate of the unfortunate toads.

DeVore, J. & Maerz, J. (2014). Grass invasion increases top-down pressure on an amphibian via structurally mediated effects on an intraguild predator. *ESA Ecology*, 95, 7, 1724-1730.

The fight against ebola - reaching a cure

With the Ebola virus still at large in West Africa, projections from the World Health Organisation are indicating that the number of infections may treble before the end of the year. Experimental trials are being fast-tracked to tackle the disease, which is initially transmitted to humans from wild animals, and then spreads through human interactions.

A recent international study led by the Public Health Agency of Canada has reversed the disease in non-human primates: researchers administered a combination of antibodies, termed ZMapp, to groups of infected rhesus macaques. While the entire of an untreated control group died, the survival rate of the treated macaques was 100%, even in those displaying advanced symptoms.

The study has been hailed as a monumental success, but the scientists involved remain cautious about the unknowns between monkey and human models of infection.

Qiu, X., Wong, G., Audet, J. et al. (2014). Reversion of advanced Ebola virus disease in nonhuman primates with ZMapp. *Nature*, doi:10.1038/nature13777

Explanatory power decreasing

Explanatory power in ecology papers may be on the decline. According to a meta-analysis of over 18000 articles published by renowned ecological societies, the number of P values reported per paper is steadily increasing in line with an increase in study complexity. In contrast, the values of reported coefficients of determination are falling, suggesting overall explanatory power is decreasing. These findings may be the result of a number of changes: studies becoming more specific, the manner in which ecology is studied, and ongoing changes in the how results and findings are communicated. The authors suggest that to determine the exact reasons, however, would require a thorough and critical review of the scientific process.

Low-Decarie, E, Chivers, C & Granados, M. (2014). Rising complexity and falling explanatory power in ecology. ***Frontiers in Ecology and the Environment,*** **12, 412-418. doi:10.1371**

Specialised reef species

Biodiversity alone may not be enough to ensure survival of coral reefs. Instead, researchers from the Coral CoE have suggested that specialised species are critical to reef ecosystems, performing vital, unique roles. The researchers examined the roles of over six thousand coral reef fish species across 169 locations. Parrotfish are cited as an example of an irreplaceable species, as they are unique in cleaning inshore coral reefs. Loss of a key species could be catastrophic, making the reef vulnerable if there are no similar species to replace them, and the study highlights their protection is paramount.

Mouillot, D., Villeger, S., Parravacini, V. et al. (2014). Functional over-redundancy and high functional vulnerability in global fish faunas on tropical reefs. ***PNAS USA,*** **doi:10.1073/pnas.1317625111**

Subglacial ecosystem discovered

Researchers funded by the National Science Foundation recently confirmed the presence of viable ecosystems an incredible 800m below the West Antarctic ice sheet. Samples taken from the subglacial Lake Whillans were analysed, and a large and diverse microbial community was discovered.

The study provides a fascinating glimpse into life that may exist in the waters beneath the Antarctic ice sheet. It is believed that over 400 subglacial lakes, rivers and streams exist under the continent, and the presence of viable ecosystems could have a strong influence on the biological composition of the Southern Ocean, the vast body of water that surrounds Antarctica.

Christner, B., Priscu, J., Achberger, A. et al. (2014). A microbial ecosystem beneath the West Antarctic ice sheet. ***Nature,*** **512, 310-313.**

Hatching time

The first evidence of environmentally-cued hatching has been demonstrated in amphibians. A recent study has discovered Hansen's tree frogs from Vietnam and Cambodia adjusting their life cycle in response to predation. By monitoring egg clutches, researchers found that in clutches where eggs had been removed, remaining eggs hatched much sooner than clutches left undisturbed. In addition, when katydids - a common predator of the frog - predated on a clutch, surviving eggs would hatch within an hour of the event. This speedy hatching appears to be a direct result of the predation. It demonstrates a response to changes in the environment, perhaps a chemical cue, and highlights potentially vital flexibility in the life history of the species.

Poo, S. & Bickford, D.P. (2014). Hatching plasticity in a Southeast Asian tree frog. ***Behavioral Ecology and Sociobiology.*** **DOI 10.1007/s00265-014-1781-0.**

NEW SPECIES LINE UP

BEAUTIFUL *BOOPHIS*

Boophis ankarafensis, named after its home - Ankarafa forest, can be distinguished by its advertisement call & genetic divergence. The only member of the group endemic to western Madagascar.

DEEP SEA *DENDROGRAMMA*

Collected in 1986, these deep sea animals have been classified into 2 new species. under a whole new genus. Their closest relationships remain a mystery - as their preservation rules out genetic analysis.

FIVE NEW SAKI MONKEYS

After the taxonomic revision of the genus researchers now propose there are 16 distinct species, not just subspecies. The five new species are confined to Brazil, Peru and Bolivia

SAUDI CORAL SPECIES

A new species of hard coral *Pachyseris inattesa* has been described from the Saudi Arabian red sea. The researchers hope this will highlight the opportunities for discovery in the region.

NEW SPECIES LINE UP

SUPERSIZE NEW DINO SPECIES

Dreadnoughtus Schrani is huge, 26m long and weighing in at about 65 tonnes. With the most complete skeleton ever found of its type. Over 70% of its bones were uncovered in Patagonia.

SHORT RIDGED *SPASSKIA*

Researchers in china discovered members of the genus *Spasskia* for the first time, and described a new species *S. brevicarinata*. Defined by short ridges on its body, for which it get its name.

ONE MORE ORCHID

Dichaea bragae, named in memory of 'orchidologist' Dr. Pedro Ivo Soares Braga. Found in Northern Brazil, it joins part the largest genus in the subtribe Zygopetalinae.

PICKING UP NEW SPECIES AT THE SHOPS

The mushrooms you're eating might not even be known to science. Mycologists identified three new species by popping to the local grocers. And then sequencing their DNA of course.

Salamanders eat the same, after all

Salamanders braving the climb up trees aren't doing so for food as originally believed, a new study has discovered. By capturing red-legged salamanders on the ground and from higher vegetation and trees, researchers from the University of Missouri were able to determine if a particular delicacy was driving the tree-climbing. Stomach contents were pumped before the salamanders were released unharmed, and surprisingly, the same range of beetles, mites and ants were found. The salamanders collected from trees were not feasting on anything different to those remaining on the ground. Predator avoidance or competition are suggested as possible alternative reasons for the tree-climbing behaviour.

Lewis, J., Connette, G., Deyrup, M. et al (2014). Relationship between diet and microhabitat use of red-legged salamanders *(Plethodon shermani)* in southwestern North Carolina. *Copeia,* 2014 (2), 201-205.

City slicker spiders

City-dwelling spiders may be larger and have increased reproductive ability. Researchers from the University of Sydney studied physical attributes of orb-weaving spiders, a species found in urban and natural environments, and found differences in size and fat reserves. Ovary weight, a key indicator of fecundity, also differed between environments. Larger body sizes and increased ovary-weight were associated with orb-weavers in urban areas, while smaller body size was associated with areas of increased vegetation. The findings suggest that some species benefit from urbanisation and its associated environmental changes.

Lowe, E., Wilder, S. & Hochuli, D. (2014). Urbanisation at multiple scales is associated with larger size and higher fecundity of an orb-weaving spider. *PLoS One.* DOI: 10.1371/journal.ponc.0105480

Castrated and gigantic

Water fleas have been found to balloon to gigantic proportions when parasitised by *Pasteuria ramosa*. Researchers studied the host-parasite system and found the interaction involves the castration of the flea.

The study manipulated feeding schedules of fleas and discovered that faster growth in the parasite is associated with less energy allocated to reproduction by the flea. By castrating it, *P. ramosa* forces the flea to concentrate on growth - leading to gigantism, and improving energy gain for the parasite itself.

Cressler, C, Nelson, W, Day, T & McCauley, E. (2014). Starvation reveals the cause of infection-induced castration and gigantism. Proceedings of the Royal Society B, doi:10.1098/rspb.2014.1087

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CONSERVATION in BRIEF

SHARK & MANTA BAN

New legislation is in place to ensure that five species of sharks and manta rays are harvested sustainably. The regulations agreed by CITES now require traders to have permits to legally trade the oceanic whitetip, the porbeagle, the manta ray, and three species of hammerhead shark.

Sharks worldwide are under threat from overfishing, a result of the demand for shark fin soup, and in the case of the manta ray, a belief in medicinal properties of its gills. Fished sustainably, these species will have a chance to recover - and the new regulations are an important step in the right direction.

While 180 countries have agreed to abide by the new ruling, including China - the main consumer market, several countries have registered reservations and will continue to fish for the vulnerable species.

The ivory trade is once more on a deadly rise. Researchers from Colorado State University have analysed data from East Africa, creating a model to quantify the continuing ivory harvest, and discovered alarming declines in elephant populations.

After the intense and horrific poaching that gripped Africa during the 1970s and 1980s, where Kenya alone lost a reported 85% of its elephants, populations were recovering. However, the devastating efforts by poachers across Africa in recent years has seen populations of this charismatic creature once again plummet alarmingly. We are all too regularly faced by images of disfigured individuals, and stories of tireless conservationists.

The study used data from carcass-monitoring and demographics from a wild population in Samburu, Kenya. This was then expanded to estimate poaching at a regional and continental scale using carcass data from CITES.

The new analysis shows illegal killing to have been on the increase since 2008 and was found to correlate with the black market price for ivory, as well as increased seizures of ivory bound for the Far East.

The researchers estimated that 40,000 elephants were killed illegally in 2011 alone, reducing the total number of the species by 3%. Preliminary data suggests the decline is continuing, with elephants being killed faster than they can reproduce. This model highlights the plight of African elephants, and will be an important method for further studying vulnerable species and providing much needed information for conservation efforts.

Wittemyer, G, Northrup, J, Blanc, J, et al (2014). Illegal killing for ivory drives global decline in African elephants. Proceedings of the National Academy of Sciences of the United States of America, 111, 36: 13117-13121.

Confirming cryptic subspecies

This fluffball isn't in our new species line up because, despite the hype, that's not actually what's happened! For a long time, scientists have been in disaccord about whether the different populations of the Philippine tarsier represent one species, different species or three different sub-species. Researchers from the University of Kansas set out to clear this up. They found that the populations should indeed be partitioned into three genetic variants, but they warn against other researchers jumping into defining it taxonomically too quickly. "We caution primatologists from taking taxonomic action until multiple lines of evidence converge on a meaningful solution" said the authors. However, they hope their findings will bolster conservation priorities and encourage practitioners to protect the genetic variation between the populations.

Brown et al. (2014) Conservation Genetics of the Philippine Tarsier: Cryptic Genetic Variation Restructures Conservation Priorities for an Island Archipelago Primate. PLoS ONE 9(8): e104340. doi:10.1371

Fracking: the costs and benefits

Hydraulic fracturing, or fracking, is the process of blasting a concoction of chemicals, water and sand deep underground at high pressure. This blast releases valuable gases from shale rock formations which can then be collected.

A study from Stanford synthesises 165 papers to assess the impacts of this activity on the environment and its benefits regarding resource usage. Extracting natural gases using fracking is found to compare well with conventional energy sources: though fracking uses more water than gas drilling, the use of natural gas in place of coal or nuclear fuel saves water.

Of concern though is the potential contamination of drinking water by gas and toxins from the fracking process. The study finds that, while not common, contamination does occur. Long-term effects of released toxins slowly seeping up remain unknown.

The debate is likely to rage on, with potential environmental and health damages at war with the monetary gains to be made from the natural gases.

Jackson, R, Vengosh, A, Carey, W, Davies, R, Darrah, T, O'Sullivan, F, & Petron, G (2014). The environmental costs and benefits of fracking. Annual Review of Environment and Resources, 39: 1-7. e104340. doi:10.1371

Primary forests should be protected

Deforestation is rapid and widespread, with primary forests across the planet continuing to be devastated at startling rates. They are irreplaceable, containing remarkable biodiversity. A recent study by an international group of researchers investigated global distribution of primary forests, and identifies policies that would ensure their survival into the future. The researchers recommend primary forests are recognised as of global concern and incorporated into environmental accounting. In addition, promoting the importance of avoiding further loss and recognising the role of indigenous and community conserved areas. It is clear that protection is needed. A meta-analysis of 86 studies examining protected areas (PAs) allowed researchers to determine

that they have higher abundance of species, higher assemblage abundances, and higher species richness values than unprotected areas. The study provides compelling evidence for the effectiveness of PAs and additional support for policies concerning the protection of primary forests.

Mackey, B., DellaSalla, D., Kormos, C., et al. (2014). Policy options for the world's primary forests in multilateral environmental agreements. *Conservation Letters*, doi: 10.1111/conl.12120

Coetzee, B., Gaston, K. & Chown, S.. (2014). Local scale comparisons of biodiversity as a test for global protected area ecological performance: a meta-analysis. *PLoS One*, 9, 8. doi:10.1371/journal.pone.0105824

Novel is not acceptable

A novel ecosystem develops when human activities drive changes in biological communities, via environmental change and the introduction of invasive species. Due to the prevalence of novel ecosystems, some ecologists and politicians act as if they are the new normal.

However, a study from the University of Tennessee argues this is a dangerous line of thought. The researchers suggest that adopting novel ecosystems so readily would be a serious threat, damaging ecosystems that have evolved over long periods of time and leading to more harm

caused by invasive species. Instead, they advise caution, applying conservation methods that would allow restored systems time to adapt to environmental changes in line with historical trajectories.

Murcia, C, Aronson, J, Kattan, G, Moreno-Mateos, D, Dixon, K, & Simberloff, D (2014). A critique of the 'novel ecosystem' concept. Trends in Ecology & Evolution, 29, 10: 548-543.

Troubled tapirs

Despite hunting restrictions, populations of tapir in French Guiana may continue to decline. The tapir is the largest herbivore in the Amazon basin, and an important part of the rainforest ecosystem. Four years worth of camera trap data indicates that additional hunting restrictions would be needed to prevent over-harvesting to cause the vulnerable populations to drop even further.

Tobler, M, Hilbert, H, Debeir, L & Richard-Hansen, C. (2014). Estimates of density and sustainable harvest of the lowland tapir *Tapirus terrestris* in the Amazon of French Guiana using a Bayesian spatially explicit capture–recapture model. Oryx, 48, 3: 410-419.

Bolstered blues

During the 20th century, whaling took such a heavy toll that blue whale was placed on the IUCN list as endangered. New research examining the impact of ship strikes has discovered that the blue whale population of the eastern North Pacific is now back up to 97% of its historic numbers. The study indicates that while ship strikes do occur, they have minimal impact on blue whale population trends - a good news story for this species.

Monnahan, C, Branch, T & Punt, A. (2014). Do ship strikes threaten the recovery of endangered eastern North Pacific blue whales? Marine Mammal Science DOI: 10.1111/mms.12157

CLIMATE CHANGE in BRIEF

Strange swimmers

A quarter of the world's sharks are already at risk of extinction, and warming ocean temperatures aren't going to help matters. As more carbon dioxide is released into the atmosphere, more is absorbed into the oceans, and this has led to surface waters that are now 30% more acidic. Our atmosphere currently contains around 400 parts per million of carbon dioxide, but this is expected to rise to 1,000 by 2100, with a lowering of the pH level from 8.1 to 7.7-7.8.

Ocean species are quite variable in how they respond to this in tests. Some are plastic and can adapt well to the changes, whilst others suffer drastically, losing their senses, increasing anxiety or reducing survival. New research has found small-spotted catfish in acidified water exhibit some strange behaviours - sometimes

swimming for up to an hour continuously. As usual stop-start swimmers, this was odd. The researchers suggest it could be a result of ion concentrations in the brain, or a relentless escape behaviour. Sharks have slow life histories, taking many years to reproduce. This isn't a good thing - giving the species less generations to evolve to changes and requiring them to be behaviourally plastic - which apparently they might not be able to do.

Green, L. & Jutfelt, F. (2014). Elevated carbon dioxide alters the plasma composition and behaviour of a shark. *Biology Letters*, 10 (9) doi: 10.1098/rsbl.2014.0538

Rabbitfish rampage

Tropical rabbitfish have already destroyed important algal forests in the eastern Mediterranean Sea, but a new study suggests they could be a threat to the entire Mediterranean basin if they continue to expand their ranges.

The study identified contrasting areas - those where the rabbitfish were abundant, and those where they were absent. Where rabbitfish existed, there was a 65% reduction

in large seaweeds, 60% reduction in other algae and invertebrates and a 40% reduction in the overall species diversity. These regions had been left as 'rocky barrens'.

The rabbitfish are from two separate species, and their ranges are spreading due to warming ocean temperatures. Unfortunately, these species having filled two slightly separate niches is what is driving the loss of species diversity in the Mediterranean. One of the rabbitfish eats adult forms of algae and seaweed, directly competing with native fish. However the other eats the algae in its juvenile form, and together the two species wipe out entire areas that are vital to hundreds of species for food and habitat.

Verges, A., Tomas, F., Cebrian, E. et al. (2014) Tropical rabbitfish and the deforestation of a warming temperate sea. *Journal of Ecology* DOI: 10.1111/1365-2745.12324

Digging the pupfish out of its hole

The Devil's hole pupfish is a desert fish living in its namesake's cavern - The Devil's Hole. Their population fluctuates with the seasons, but their recorded number is just 92. Scientists have recently reported that the geothermal water in which the pupfish live is heating up as a result of climate change, and it doesn't look set to cool down. These little fish are currently surviving in waters of 93 degrees, and because of the increasing temperatures the fish larvae have less time to hatch from their eggs during the optimal period in which the temperature is warm enough for the eggs to hatch, but there is still enough food available for them to mature. This time period has shortened by a week, and has led to declines in the adult population. Several populations have been established in artificial pools that mimic the geothermal properties of Devil's Hole, but all of them have failed. Further research has modelled the risks of intervention, and determined removing eggs for ex situ conservation has the least impact. However, the median number of years predicted before extinction was just 26-27. Not long to dig this species out of its hot hole.

Hausner, M.B., Wilson, K.P., Gaines, B. et al. (2014). Life in a fishbowl: Prospects for the endangered Devils Hole pupfish (Cyprinodon diabolis) in a changing climate. *Water Resources Research*. 50 (8) pp7020-7034. DOI: 10.1002/2014WR015511

Beissinger, S.R. (2014) Digging the pupfish out of its hole: risk analyses to guide harvest of Devils Hole pupfish for captive breeding. *PeerJ* 2:e549

All calm on the ladybird front

We're all familiar with news about rising temperatures and melting ice caps, but it is also calming winds - known as 'global stilling' - and this could be particularly important for predator-prey relationships.

The North and South Poles are increasing in temprature much faster than equatorial regions, which disrupts the temperature differential that creates wind. In addition to this, buildings and other structures reduce windspeeds and these effects combinded are expected to reduce windspeeds in midwest America by up to 15% during the 21st century.

Highlighting the sometimes random ways in which research questions might come to light, the lead author Brandon Barton described how he was standing in a cornfield one day as a big gust of wind came by, leading him to wonder what effect the wind has on animals living in such environments.

Brandon tested the effect of wind on the predator prey interaction between Asian ladybirds and soybean aphids. In laboratory tests, the aphids were unaffected by wind speeds directly. He then took his experiment to the field, with two field types that were either sheltered from the wind or exposed. He found that the ladybirds were more abundant where there was less wind, and they subsequently reduced the aphid population by up to 40%. He found that the way that the wind makes the soybean crops move hinders the ladybirds, and it takes them up to 30% longer to get to start eating the aphids.

Whilst this study may have practical applications for agricultural uses, it's also important to illustrate how a reduction in windspeed over the course of the century, from climate change and human expansion, can disrupt populations of the tiniest organisms that you might not have otherwise given a second thought.

Barton, B.T. (2014). Reduced wind strengthens top-down control of an insect herbivore. *Ecology*, 95(9) pp. 2375–2381

Here's the heat

Whether climate change is happening isn't a debate - it's a fact. But that won't stop disbelievers from clutching on to figures that bolster their cause. One of the most often used is that for the last 17 years, there has apparently been no increase globally in average surface temperatures and therefore - no global warming.

Bodies of evidence debunk this, indicating that most of the heat generated from carbon emissions is absorbed into the ocean instead of the atmosphere. A new study takes it one step further, and explains why, and where the heat goes.

The study explains that a lot of the heat is stored deep in the Atlantic Ocean, facilitated by a current that sped up at the beginning of the 21st century, drawing in heat almost a mile into its depths. Since 2000, the North and South Atlantic Oceans have been storing more energy than the rest of the world's oceans combined.

Brown et al. (2014) Varying planetary heat sink led to global-warming slowdown and acceleration. *Science*, 345 (6199), pp 897-903. DOI: 10.1126/science.1254937

Ferocious fire

With increasing temperatures and longer droughts, climate change is expected to contribute to a 200% increase in forest fire damage in Europe by 2090, according to a new study. However - it doesn't have to be that drastic. The study indicates that the use of preventive fires could reduce this to an increase of just 50%.

Researchers from the International Institute for Applied System Sciences worked alongside colleagues from the Joint Research Centre and national forest representatives from EU countries and the EU expert group on forest fires to understand the potential impacts, and what should be done about it.

Preventive, or prescribed burning is a hotly debated topic, but this study suggests that it could be a useful management tool to protect European forests. Prescribed burns reduce the damaging effects of uncontrollable fires by removing highly flammable dead wood.

However, the researchers note that we could prevent 95% of forest fires by being more personally responsible when lighting campfires and putting out cigarettes.

Brown et al. (2014) Forest fires and adaptation options in Europe. *Regional Environmental Change*/ DOI 10.1007/s10113-014-0621-0

EVOLUTION in BRIEF

These fins are made for walkin'

Fish took the first step on to land approximately 400 million years ago, and those early explorations led to the evolution of tetrapods. The process behind this evolution and how fish used their bodies for terrestrial locomotion was recently investigated.

Polypterus senegalus is an impressive African fish that can walk on land and breathe air, and is comparable in morphology to ancient stem tetrapod fish. It is therefore an excellent study species to learn more about the transition from sea to land. Researchers raised a group of juvenile *Polypterus* in a terrestrial environment for almost a year ('terrestrialised'), and complex aspects of their behaviour, biomechanical responses, and anatomy were compared to juveniles raised in water.

The changes were significant: the terrestrialised fish were found to lift their heads higher and hold their fins closer to their bodies, allowing them to walk more efficiently than the fish raised in water. Changes to the clavicle and cleithrum (part of a supporting brace that links the head and body) were also noted, allowing the fish raised on land more space for their pectoral fins to move. Both behavioural and anatomical changes appear to mirror those found in the fossil record, and the researchers suggest they reflect changes fish would have undergone during their first forays on to land.

This unique study highlights remarkable developmental plasticity in *Polypterus* in response to changes in its environment. Such plasticity in ancient fish could have been the key in facilitating the evolution of traits that allowed species to explore terrestrial environments more effectively, leading to the evolution of the tetrapod.

Standen, E., Du, T. & Larsson, H. (2014). Developmental plasticity and the origin of tetrapods. *Nature*, 513, 54-58.

Complex cichlids diversity

In the Great Lakes of East Africa, cichlid fish are well known for their phenotypic diversity - with almost 1500 species already identified. Scientists have recently sequenced genomes in an effort to understand the mechanisms behind the rapid evolution of so many new species of cichlid.

By analysing five species of cichlid, representing five different lineages, the international research team was able to highlight the complex genomic mechanisms that may lead to the extraordinary rate of diversification in cichlids.

The study concludes that neutral processes have contributed to the growth of genomic variation, and selection has played a role in sorting it. The interaction between these neutral and adaptive processes appears to have driven the rapid and diverse evolution of new cichlid phenotypes.

Brawand, D., Wagner, C., Li, Y. et al. (2014). The genomic substrate for adaptive radiation in African cichlid fish. *Nature*, 513, 375-381.

Sneaky cichlids

In East African cichlid fish, during development males adopt one of two strategies. They either grow big - showing off their quality and out-competing other males to gain access to females for spawning, or they halt their growth when they are up to 40 times smaller than they could be. This cichlid represents the most extreme male polymorphism there is.

Larger males attract females by collecting large numbers of shells. If they're good enough, the female will lay her eggs inside them. The hefty male cannot access the inside of these shells so he releases his sperm outside of them. However, the study details how the smaller male is perfectly sized to enter the shells and fertilise the eggs directly. They are able to get so close to the eggs that they are more successful at fertilisation even when drastically out-proportioned.

This study found that each morph of the male is determined by a 2 allele gene on the male sex chromosome. It's the first study of its kind to demonstrate the inheritance mechanism for polymorphic males, and highlights the combination between ecological and genetic mechanisms that drive morphological diversity.

Wirtz-Ocana, S., Meidl, P., Bonfils, D. et al. (2014) Y-linked Mendelian inheritance of giant and dwarf male morphs in shell-brooding cichlids. *Proc B.* 281 (1794). DOI: 10.1098/rspb.2014.0253

Collapse of the carvings

Egyptian tombs have been able to provide a fascinating insight into ancient hunting and the subsequent collapse of an ecological network. An interdisciplinary team analysed artwork depicting ancient hunting scenes, and were able to track extinctions over time. The research explored the vulnerability of the ecological networks based on a timeline of extinctions, and their model highlighted the alarming manner in which an extinction impacts on the resilience of an ecosystem. The drop from 37 large mammal species over 5000 years ago to the current number of 8 left in Egypt means the surviving species are currently more vulnerable than ever before. The study is believed to be the first to analyse ecological impacts on predator-prey networks over such a large time-scale, revealing how these ancient impacts can shape modern ecosystems.

Yeakel, J,. Pires, M., Rudolf, L., et al. (2014). Collapse of an ecological network in Ancient Egypt. *PNAS*, doi: 10.1073/pnas.1408471111

Jumping gibbon genomes

A gibbon in full swing is an incredible sight. Travelling through tree canopies, they can reach speeds of above 35 miles per hour, and a single swing can propel them an amazing 15 metres. Scientists have recently decoded the gibbon genome to uncover the secrets of its dexterity, and how it adapted to the high life.

Gibbons were the first of the apes to deviate from the common ancestor they share with humans and monkeys. In addition, they are thought to have many more chromosomal rearrangements - duplications and deletions that are of particular interest to geneticists.

An international team discovered that gibbon chromosomes are 'peculiar', with stretches of DNA that can change positions in the genome. This makes gibbons unique as the only primates in which this 'jumping gene' is found. Its effect is to make the genome more prone to chromosomal rearrangements - an event that may stop two individuals from breeding, and thus hasten speciation.

The team also found that genes associated with bone and cartilage development had evolved more quickly in gibbons than other apes. This is part of the reason gibbons are uniquely talented in tree-top travel.

Despite their strengths, gibbons are still vulnerable in their disappearing tropical forest homes of South-East Asia, with some species close to extinction. In addition to the insights gained into gibbon dexterity, the researchers hope that the genome decoding will aid conservation efforts of these vulnerable populations.

Carbone, L., Harris, A., Gnerre, S., et al. (2014). Gibbon genome and the fast karyotype evolution of small apes. *Nature*, 513, 195-201.

Not so passive drivers of diversity

Traditionally, it is believed that speciation is associated with long-term changes to the landscape. A mountain rising or a river changing course can segment populations, isolating smaller groups that will eventually become a different species. The Neotropics is an area that stretches from the southern tip of South America up to Mexico. It contains a remarkable array of bird species and is of interest to scientists attempting to understand how such biodiversity arises.

Tropical bird speciation has long been thought to be a result of geological and climate changes, in line with the traditional model. A new study has challenged this view, however, suggesting instead that bird speciation in the Neotropics is driven by movements of birds across the geographical barriers, such as mountains and rivers, rather than those features arising within them.

Researchers analysed genetic patterns from lineages of Neotropic bird populations and were able to estimate when populations that were divided by geographical barriers became distinct. Speciation of birds in the Neotropics was found to have occurred around 2.6 million years ago, long after the origins of the Andes mountains and Amazon river systems - compelling evidence for speciation being driven by active movements across these barriers.

Tilston-Smith, B., McCormack, J., Cuervo, A. et al. (2014). The drivers of tropical speciation. Nature, doi:10.1038/nature13687

BEHAVIOUR in BRIEF

A green migration

Many species fly looped migrations - taking one route in spring and another in autumn. For those in eastern North America their paths made sense - they were making use of strong southerly tailwinds in spring and less severe headwinds in fall. But this wasn't the case for eastern North American migrators, and up until now it had researchers stumped.

When migrating in spring to their breeding grounds, it turns out the eastern species follow a green wave of plant and insect abundance. When migrating back to their wintering grounds there is little food to utilise, so they take the most direct route on the way to warmer climes. The green wave isn't a new concept, but this is the first time it has been demonstrated for insectivorous species.

La Sorte, F.A., Fink, D., Hochachka, W.M. et al. (2014) Spring phenology of ecological productivity contributes to the use of looped migration strategies by birds. *Proc B.* 281 (1793) DOI: 10.1098/rspb.2014.0984

A friendly hello

Last year it was discovered that bottlenose dolphins each have their own 'signature whistle' that they use when encountering another individual, and this individual will then repeat the signal back to them. The authors of this paper knew that it occurs between close associates, but in a new study they have investigated whether these interactions are always affiliative, or whether they can also serve to manage aggression.

In the study, dolphins would produce their own unique signature whistle and this would then be played back to them by the researchers. The dolphins were found to consistently repeat the whistle again when they had been matched in this way.

In other species that employ vocal matching, such as song sparrows, the very act of matching another's song is an exhibition of aggressive intent. However, during the playback experiments the researchers found no signals of aggressive behaviour, and concluded that these were indeed affiliative signals that allowed the dolphins to address their companions.

The study also found that timing was important in order to establish this interaction. The dolphin's signature whistle had to be played back within a second in order to most successfully elicit their repetition. This is particularly interesting as it has previously been seen between some birds that a rapid vocal matching specifically can be an indication of aggression. However, the bottlenose dolphins seem to be using these repetitions as just friendly hellos to their nearest and dearest.

King, S., Harley, H.E. & Janik, V.M. (2014). The role of signature whistle matching in bottlenose dolphins, Tursiops truncatus, *Animal Behaviour.* Vol 96; pp 79-88 DOI: 10.1016/j.anbehav.2014.07.019

Better friends make for bolder spiders

Have you ever noticed the longer you spend around your friends the more outgoing you feel? Well socialising can affect a spider's personality too. Measuring personality in terms of boldness is a common experiement in zoology. In this study, researchers disturbed colonies of *Stegodyphus dumicola* social spiders. Some they left to rebuild their group nest together, and the others they mixed up so their social groups were disturbed. They then tested the spiders' boldness by blowing air at them. The faster a spider would move after being blown, the more bold was its personality. Spiders mixed with strangers had less consitent personality responses and were overall more shy. Living in the same group with the same 8 legged companions allows a spider to be confident in its own social niche, and know how to avoid conflict with its group members - increasing the consistency with which it exhibits boldness.

Modlmeier, A.P., Laskowski, K.L., DeMarco, A.E. et al (2014). Persistent social interactions beget more pronounced personalities in a desert-dwelling social spider. *Biology Letters*, 10 (8) DOI: 10.1098/rsbl.2014.0419

Cryptic behaviour

Many moths employ clever methods of camouflage in order to avoid finding themselves on the menu of a hungry bird. These can include simple crypsis - resembling their background in colour and pattern, and disruptive colouration - a mechanism that hinders detection of the moth's outline. However, a recent study has now shown that behavioural choice and body orientation are also vital parts of a moth's predator avoidance strategy when at rest.

An international team of researchers used avian vision models and image analysis of two species of bark-resting moths to investigate camouflage mechanisms. Whilst previous camouflage research has used artificial systems, the key here was to study real species in their natural environments.

Findings suggest that both species improve their camouflage via behavioural choice of background and body orientation, highlighting the adaptive significance of the interplay of behavioural choice with crypsis and disruptive colouration.

Kang, C, Stevens, M, Moon, J-y, et al. (2014). Camouflage through behaviour in moths: the role of background matching and disruptive colouration. *Behavioural Ecology*, doi: 10.1093/

Caring crustaceans

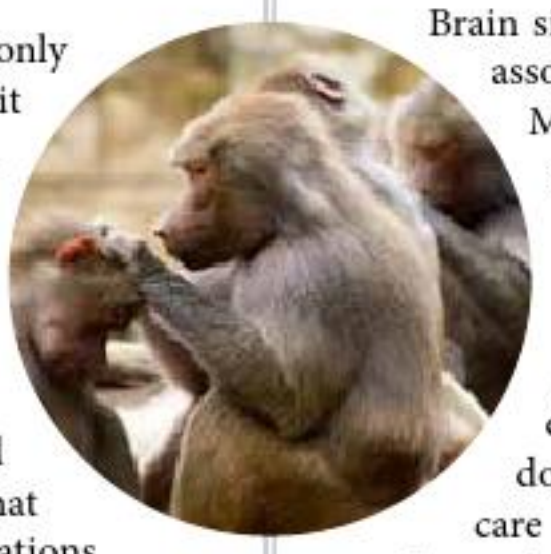
Invertebrates aren't well known for their parental care. It does occur though, particularly in species with relatively few young. A new study has found evidence for changes in the parental care performed by some amphipod crustaceans.

Researchers investigated parental care changes in response to predator cues and the threat of parasitic infection. While there was no evidence for changes in brooding behaviour in response to infection, predator cues triggered responses. In both species of amphipod crustaceans investigated in the study, active brood care was reduced when exposed to predator cues.

These findings highlight the importance of the trade off between keeping your current offsping alive, or keeping yourself alive so you can reproduce in the future.

Arundell, K., Wedell, N. & Dunn, A. (2014). The impact of predation risk and of parasitic infection on parental care in brooding crustaceans. *Animal Behaviour*, 96, 97-105.

Social survival



Social integration is not only important for humans, it matters for nonhuman primates too. In the most comprehensive study of the effect of social relationships on survival to date, researchers discovered that female baboons that maintain strong affiliations with both sexes live longer. Reasons range from reducing chronic stress and boosting immune function to improving her access to food and water.

Archie, E., Tung, J., Clark, M. et al (2014). Social affiliation matters: both same-sex and opposite-sex relationships predict survival in wild female baboons. *Proc B*. doi:10.1098/rspb.2014.1261

Bigger brains make better dads

Brain size in sticklebacks may be associated with parental care. Male common sticklebacks are well known to care for their offspring rather than the female. However, male white sticklebacks do not. The researchers discovered that males who do demonstrate parental care have larger brains than those who don't. Evidence was also found of the white stickleback evolving a smaller brain at around the same time the males stopped caring for their young.

Samuk, K, Iritani, D & Schluter, D. (2014). Reversed brain size sexual dimorphism accompanies loss of parental care in white sticklebacks. Ecology and Evolution, 4 (6), 3236-3243.

Vultures follow for food

Vultures are the only vertebrates that feed exclusively on dead animals. Finding carcasses can be difficult and unpredictable, so the social birds are known to rely on each other to find food. However, new research indicates they don't confine this to their own species.

The researchers used game theory models, which predict when individuals should cooperate and when they should cheat, as well as direct data from the Kenyan field to study the feeding behaviour of two species of endangered vulture. It turns out that vultures rely on cues from tawny and steppe eagles. They follow the sharp eyed birds of prey who are better

able to spot and rip open a carcass before pushing them off and claiming the meal as their own. This study highlights the importance of integrated management strategies for these endangered vultures.

Kane, A., Jackson, A.L., Ogada, D.L. et al. (2014) Vultures acquire information on carcass location from scavenging eagles. *Proc B*. 281 (1793), DOI: 10.1098/rspb.2014.1072

ASK FOR HELP

(Then ignore it)

Words by Professor Rosie Woodroffe for The Conversation

Bovine tuberculosis (TB) is expected to cost British taxpayers nearly £100m in 2014. Scientific evidence is a vital weapon in the fight to protect cattle from TB. Why, then, has the government just fought and won a legal battle to avoid consulting independent scientists on its most high-profile TB control effort?

Wild badgers play a role in transmitting TB to cattle, and culling badgers seems an obvious solution. A new round of badger culls is about to start, but it is risky . A complex interaction between badger behaviour and TB transmission means that the results of culling could, depending on various factors, increase TB levels, instead of reducing them. To add to that, badger culling is expensive. This is why, in 2013, the government started a pilot that it hoped would give them a cheap and effective way to control cattle TB. Farmers, rather than government, would pay for the culling and, rather than being cage-trapped, badgers would be shot in the wild.

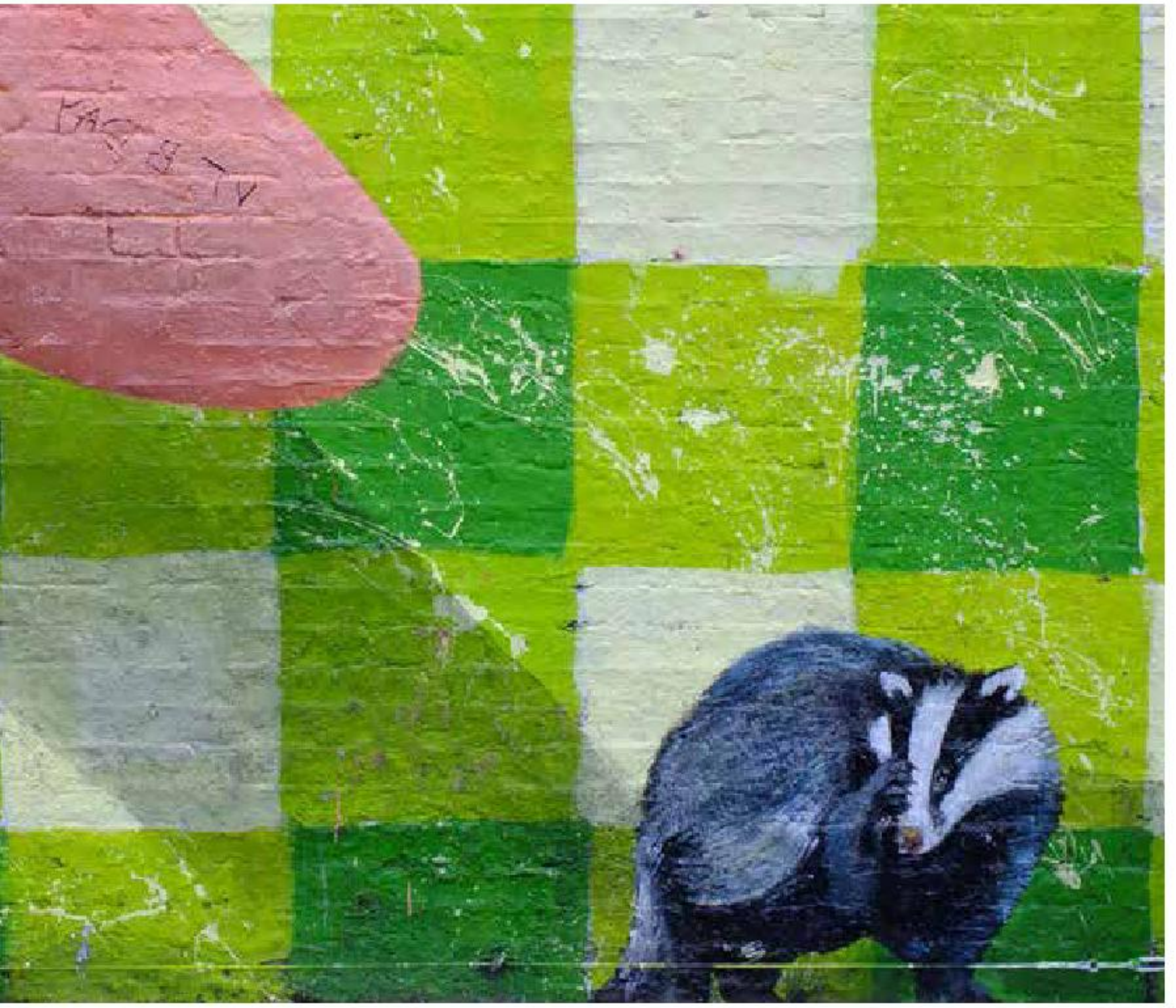
This pilot was started in just two areas – and for good reason: the whole approach was untested, and the stakes were high. Marksmen shooting at night might endanger public safety. Shooting free-ranging badgers might cause suffering. And, worst of all for the aims of the approach, failing to kill enough badgers, fast enough, would worsen the cattle TB situation that the culls were intended to control. In the face of such uncertainty, the government adopted a commonly used approach. It appointed an Independent Expert Panel to assess the safety, humaneness and effectiveness of the pilot project. The expectation was that this panel's conclusions would reflect scientific evidence, whether or not they supported government policy.

The Independent Expert Panel found that farmer-led culling was far from effective. Tasked with killing at least 70% of the local badgers within a six-week period, cull teams only managed to kill between 28% and 48%. Culling periods were extended, but still the total kill rose to only something between 31% and 56%, according to government figures. Unless more badgers could be killed, and faster, farmer-led culling risked worsening the problem it was intended to solve.

The 2013 culls also failed to meet their targets for animal welfare. Between 7.4% and 22.8% of badgers were still alive five minutes after being shot and were assumed to have experienced "marked pain".

Despite facing these failures, the government decided to repeat culls in the same areas in 2014. If effectiveness and humaneness could be improved sufficiently, culling might be extended to more areas in 2015. If not, the government might need to reconsider their policy. One would think, then, that measuring effectiveness and humaneness would be a central goal of 2014's culls.

The Independent Expert Panel, together with government scientists, selected the most accurate and precise ways to estimate the effectiveness and humaneness of the 2013 culls. Measuring effectiveness is challenging because – being nocturnal and shy – badgers are hard to count. The panel overcame this problem



by using genetic "fingerprints" to identify badgers from hair snagged on barbed wire. They measured humaneness primarily through independent observers recording the time that shot badgers took to die. The panel recommended that the same approaches be used for subsequent culls. But the government rejected this recommendation. This year there will be no attempt to count badgers in the cull areas, either before or after the culls. The time badgers take to die will not be recorded. There will be no oversight by independent scientists.

Instead, the effectiveness of the culls which started in September will be judged using a method so utterly inadequate it was barely considered in 2013. Key data will be collected by marksmen themselves: people with a vested interest in the cull being designated "effective" and "humane", who in 2013 collected data so unreliable it was considered unusable by the panel. Available information suggests that any future claim that the 2014 culls have reduced badger numbers sufficiently to control TB will be completely baseless.

Why the change in approach? Government cites cost, and hired some expensive lawyers to defend its position when the Badger Trust sought, and eventually lost, a judicial review of the decision to scrap independent scientific oversight of this year's culls. Yet the cost of pushing forward with an ineffective culling policy would far outweigh the cost of properly assessing effectiveness and humaneness.

Government has repeatedly referred to its programme of badger culling as "science-led". One would expect a science-led policy to entail gathering reliable information on management outcomes, and using this and other evidence to inform future decisions. Choosing – against formal expert advice – to collect inconsistent, inadequate and potentially biased data is an insult to evidence-based policymaking. When ineffective culling can make a bad situation worse, failing to collect the evidence needed to evaluate future policy fails farmers, taxpayers and wildlife.

Professor Rosie Woodroffe is a Senior Research Fellow at the Zoological Society of London. **She gratefull acknowledges funding from DEFRA.**

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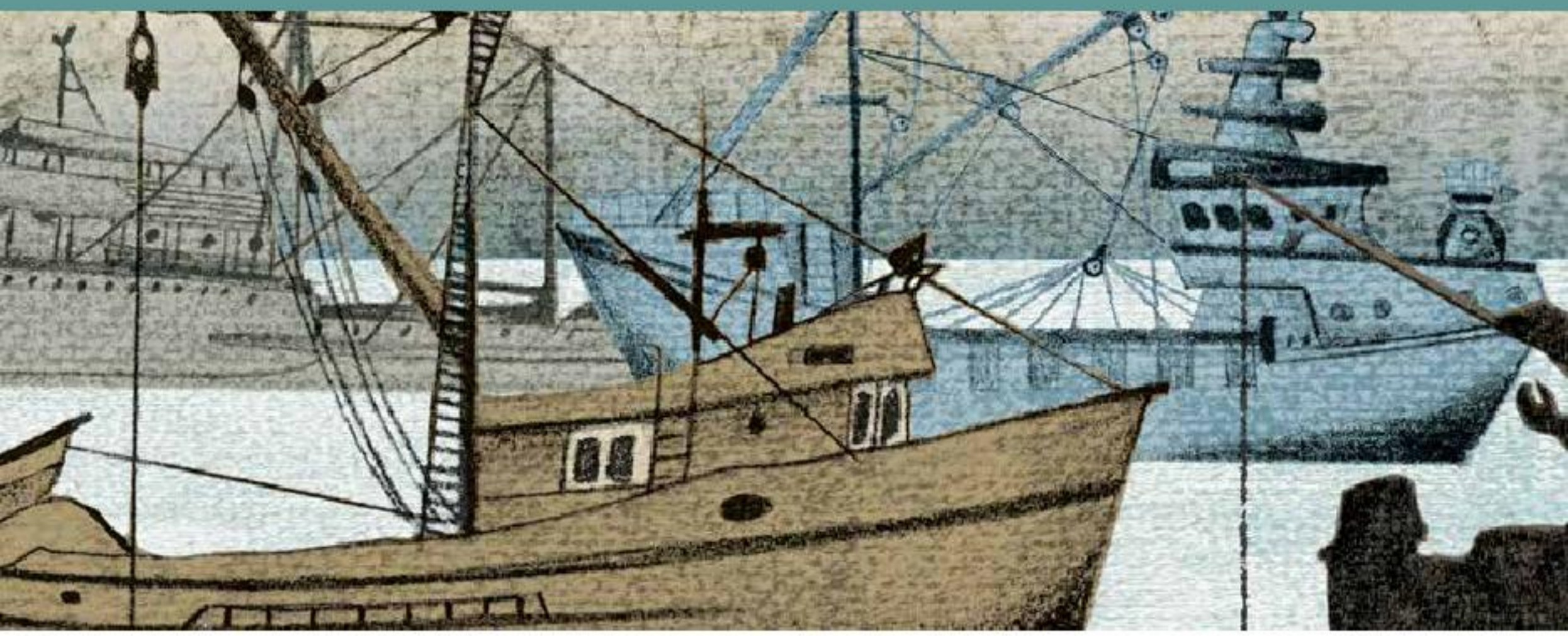
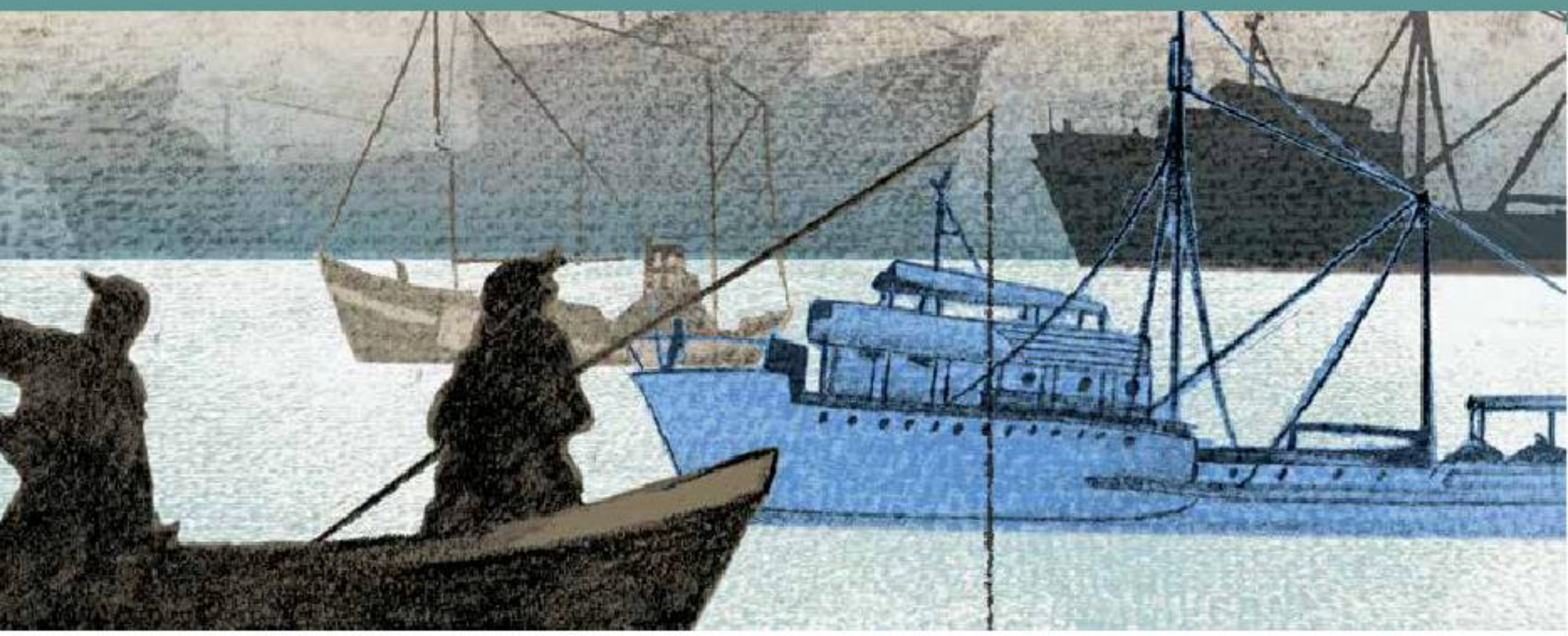


ECOLOGY MATTERS

Learning lessons from ecology will help us feed our growing population, argues Professor Mark Huxham. Illustrations by Aimee Jewitt-Harris.

Interdisciplinarity; a clumsy word for a trendy concept. In the age of the Anthropocene, when humans lurk behind most problems, doing pure ecological science seems indulgent. The need for mixed teams - with expertise from social, physical and biological sciences - seems obvious. The economists understand the market, a force as potent and mysterious as the nitrogen cycle. The engineers promise planetary prosthetics, replacing creaking natural services such as climate regulation with substitutes made of space mirrors and sulphur droplets. Ecologists should and must bring their expertise to the table, but in the face of such confident optimism what is it that they offer?

I suggest a key ecological insight is this: ecosystems are much closer to organisms than to machines. This is both simple and profound and should shape the way we relate to and attempt to manage nature. It challenges two common working assumptions of economists and engineers. The first one is the need to optimise through trade-offs. If we want to produce a machine optimised for speed then we will trade-off other features, for example by reducing weight and comfort. If we want an economy optimised for low prices, then we might reduce regulation and workers' rights. The second is the importance of facilitation and symbiosis, rather than competition. Free market economics reveres competition as the force wielded by the invisible hand



and politicians defer to this thinking when they talk of a 'global race' between economies. Ecologists study competition too, but they recognise that other interactions also matter; and it makes little sense to think of ecosystems themselves as competing. The slow processes of co-evolution and community assembly result in multiple mutual benefits and positive associations among organisms. Metaphors of machines and of free markets don't help to capture this complexity.

Let me give you some examples from my work in mangroves, those marvellously improbable green profusions found on tropical coastlines and deltas. These forests are a living rebuke to arbitrary categories and simple explanations. Are they marine or terrestrial, woods or mudflats? How can they be so productive when growing in nitrogen-starved, salt-ridden, oxygen-free mud? Why are they threatened by humanity when they are so useful? Working in this habitat imposes interdisciplinarity as foresters, microbiologists, geographers, hydrologists, economists, ecologists and others come together to tackle these questions. An understanding, and respect for, the importance of the health of these ecosystems is key. For example, mangroves rely on the tidal movement of water and are highly sensitive to changes. Rising sea-levels threaten to squeeze them between water that is too deep and increasingly developed coastal zones into which they cannot retreat. Climate change presents a major global risk. But as resilient and healthy ecosystems they also provide a local solution. Investing in root growth and trapping sediment from the sea and from rivers allows these dynamic forests to raise their game, elevating the forest floor to keep pace with the water. In fact healthy mangrove forests may display a form of systems-level homeostasis in response to sea-level rise. As the water deepens it brings more nutrient-rich sediment, which is trapped by the trees leading to better root growth, more sediment-trapping and surface elevation. This results in less inundation and hence slower growth and slowing elevation. Paleoecological evidence suggests that this mechanism has been successful in the face of past changes in sea level. It works best when there is a good mix of species, through mutual facilitation, not competition. In common with plants growing in other tough habitats, such as salt marshes and high altitude swards, individual mangrove trees often grow better when close to others, deriving a range of benefits from crowding that can overcome the costs of competition.

"This is both simple and profound"

The animal species living in these forests also scorn our categories. Whilst machine thinking involves crisp boundaries and linear flows (input/fuel → consumption/function→ waste), ecosystem boundaries are fuzzy and open with cyclical exchanges. For example many species of fish that feature on the pages of coral reef guides spend their juvenile days in the mangroves. They

link the two habitats through exchanges in nutrients and weave a functional dependency between them. Where mangroves are removed, corals may become more susceptible to smothering by algal blooms, as the populations of grazing fish are reduced. Without healthy populations of reef fish, mangroves may lose important sources of nitrogen and other nutrients. So the forests form part of an extended and mutually dependent 'coastscape' that includes river catchments, mangroves, seagrass beds and coral reefs. The best way to maintain the fisheries function of the forests is not to attempt to maximise it, but to ensure the forest as a whole is healthy and productive.

What importance do these ideas have beyond mangroves? Paul Tett, Sue Hartley, Jules Pretty and I have just published an analysis of the future of bioproductivity in this crowded and warming planet for Friends of the Earth's Big Ideas project. Crucially this includes how we might deal with the growing demands for food without undermining the ecosystems that provide it. A dominant narrative around this challenge tells us to first predict the demands and then aim to meet them, maximising productivity through the application of technology and the free market. UN projections for global population suggest an increase of around 37% to 9.6 billion by 2050. Experts predict food demand will increase by 100% or more by mid century. This discrepancy is largely because of assumptions that a 'western' diet, involving high consumption of meat and dairy products and growing obesity, will become the global norm. Whilst 'meeting consumer demand' might make sense in a free market, it should not be the function of an ecologically-informed food system. Given the current impacts on our health and our environment, it is crucial to manage demand rather than aim to simply maximise production to meet it.

Ecological thinking and research shows many routes to improved resilience in agricultural ecosystems. These may not allow a theoretical maximisation of production from the 'agricultural machine', but are compatible with modest increases in global food supply. Using nitrogen fixing 'fertilizer trees' in agri-forestry systems in Africa can significantly boost maize yields whilst also reducing soil erosion. Developing aquaculture systems that use agricultural waste as foodstuff turns linear throughputs into cycles. Establishing marine reserves to build up stocks of fish, which can move out to be caught by fishers while restoring health to ecosystems, involves prioritising long-term sustainability over short-term optimisation.

Machine-thinking in agriculture will lead to a brittle and unstable world and threatens to undermine the ecosystem services that support human and more-than-human life. Embracing the notion of ecosystem health means we need to think of a more stable future. We should prioritise mixed systems that bring bundles of services, aiming for resilience rather than maximum productivity. To do this needs the clever application of the best technologies along with a clear-headed understanding of how economies work. The talents of physical and social scientists will be essential, but the voices of ecologists – speaking of synergies, cycles and the long-term – need to be heard.

Professor Mark Huxham is Director of Academic Strategy and Professor of Teaching and Research in Environmental Biology at Edinburgh Napier University. His article on No Dominion over Nature was written for Friends of the Earth's Big Ideas Change the World project.

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SAVE IT ON A

We can have both happy farmers and happy biodiversity, for relatively little cost. Words by Dr Cristina Banks-Leite for The Conversation

Brazil's Atlantic forest – *Mata Atlântica* – is one of the world's great biodiversity hotspots, rivalling even the Amazon. Running on and off for several thousand kilometres along the coast, the forest is home to 10,000 plant species that don't exist anywhere else, more bird species than the whole of Europe, and more than half of the country's threatened animal species.

Today, the ecosystem it sustains is under threat: trees have been cleared for farms, houses and roads, big cities such as Rio de Janeiro and São Paulo have grown in the region, and just 15% of the original forest remains.

But it's not all doom and gloom for the Atlantic forest. Myself and collaborators from Universities of São Paulo, Michigan, Toronto, and UNESP, have published a study in the journal *Science* which shows that paying farmers to conserve areas of forest within their property is good value for money. The key message from our work is that it is possible to protect native species, maintain a healthy ecosystem and potentially reduce poverty, all for less than US$200m each year.

These results are interesting for at least two reasons. The first is very simple; our conclusions are not calamitous – instead of showing that it is the end of world as we know it, we show that

SHOESTRING

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human welfare and conservation needs can both be satisfied for a reasonably small amount of money. The headline number seems large, but it only represents less than 0.01% of Brazil's GDP.

The second reason is much more complicated, however. Brazil is heading for an election in October, and as it stands anything could happen. This is important as the current government is in the process of relaxing the Brazilian Forest Code which would, among other things, allow farmers to set aside a smaller proportion of their land to native habitat. This has sparked a fiery discussion among conservationists, scientists, politicians and farmers.

Previously, the code required farmers living within the Atlantic forest to set aside 20% of their land for native habitat. Farmers were prevented from designating land they couldn't use anyway such as particularly steep terrain or areas close to rivers, so many had to set aside more than 20% of their land. In theory, this was great for biodiversity; in practice it never worked as farmers didn't respect the law, often because they couldn't afford the economic costs of setting aside productive agricultural land for conservation.

The other side of the coin is that the new code is unlikely to protect the Atlantic forest's species. But, up until now, nobody knew how much habitat really was needed. What our results

Over 8000 species are found nowhere else on earth

show is that at least 30% of the forest area needs to be set aside for conservation if we are to preserve a healthy ecosystem. This is great news for Brazilian scientists and conservationists, because now they can use a number to base their arguments while discussing the changes to the Forest Code, instead of saying the usual "more the merrier".

But the suggestion that more forest is needed to preserve biodiversity doesn't mean the battle between farmers and conservationists has to continue. This is because the onus of increasing forest cover from 20% to 30% doesn't have to solely fall on farmers. There are already some schemes that pay farmers to set aside part of their land for the protection or restoration of native habitats. These schemes are usually run by local governments or NGOs and the rationale is that they are paying people to protect crucial ecosystem services, such as carbon storage, watersheds (or water quality) and the functions provided by a healthy spread of plants and animals such as pollination, or pest control.

We show that if the Brazilian government expands these schemes, then we can have both happy farmers and happy biodiversity. This does not mean that every single farm in the Atlantic forest would have to set aside 30% of its land for conservation. It also does not mean that we would protect all species from extinction, as some need 100% of pristine forest.

But if priority areas were restored to at least 30% native habitat cover, the price to pay would be less than 6.5% of what Brazil currently spends on agricultural subsidies. Farmers willing to set aside land for conservation would receive regular payments, local communities would receive the benefits of enhanced ecosystem services, and native species would be protected. Sounds like a good deal.

Whoever wins Brazil's election will have to deal with either angry farmers or angry scientists and conservationists. Our study thus reveals a promising light at the end of the tunnel – the suggestion that the new government might not need to make compromises; potentially this is a battle everybody can win.

Dr Cristina Banks-Leite is a lecturer in Life Sciences at Imperial College London. www.theconversation.com

Banks-Leite, Cristina, et al. "Using ecological thresholds to evaluate the costs and benefits of set-asides in a biodiversity hotspot." Science 345.6200 (2014): 1041-1045.

Can't get you out of my head

In one of the coolest interactions, is able to control the mind of its month has been hot for research, unravelling more of the mysteries zombifying fungus.

Words by Dr Robbie Rae, images from the Hughes Lab, Penn State

Parasites in nature abound - from festive mistletoes parasitising trees and shrubs, tounge-eating lice staking a plot in the mouth of unsuspecting fish to cuckoos placing cleverly designed eggs in the nests of birds that drop their guards. But parasites get much more clever than this and can, upon infection, manipulate the behaviour of their hosts. Snails casually grazing on bird droppings might inadvertantly eat the eggs of the parasitic flatworm Leucochloridium paradoxum. The flatworms that grow within manipulate the snail's behaviour, causing them to venture into open, sunlit spaces - making them vulnerable to predation. This particular parasite is also able to induce morphological changes. The larval form of the flatworm develops into a sporocyst, and grows into long swollen brood sacs filled with the free swimming stage of the parasite. These broodsacs are forced into the snail's eyestalks - transforming them into large, throbbing tentacles, that perfectly resemble juicy, wriggling caterpillars - or to a hungry garden bird - lunch. This is an example of 'aggressive

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"There are fungal parasites out there that could rival these mind controlling abilities"

"The fungus can recognise the brain of its host"

mimicry' whereby a parasite manipulates the host to look like food. A bird will see these perfectly positioned wriggling worms out in the open and of course consume the snail. The flatworm then reproduces and the next generation of eggs is excreted out with the bird's faeces – and so the cycle is complete.

Infection of crickets by the horsehair worm nematomorph *Spinochordodes tellinii* makes the cricket leap into swimming pools, ponds and other water sources where the parasite bursts free through the cricket's exoskeleton. But step aside, worms – because there are fungal parasites out there that could rival these mind controlling abilities. Carpenter ants (genus *Camponotus*) show a remarkable behaviour when infected with Cordyceps fungus. Upon infection, the fungus infiltrates and manipulates the brain – causing the ants to convulse and fall away from their colony. Then overcome, the ant climbs up high into the foliage and bites tightly onto the underside of a leaf with its mandibles - aptly known as the "death grip". Once clamped in to the perfect conditions, hypahae harden the exoskeleton and secure the body to the leaf. Within days, the fruiting body of the fungus sprouts from the carcass. The benefit to the fungus is that when it reproduces in the ant its fungal spores are spread from the fruiting body across the forest via the wind – infecting other ants within the area. Hence, it is important for the fungus to get as high as possible away from the forest floor to access the wind streams above - ensuring maximum dispersal.

Although this is fascinating in itself, the molecular mechanisms involved are poorly understood. But Charissa de Bekker and colleages have started to shed light on the chemical compounds that are used by these parasites. The authors were aware that Cordyceps fungi only infect specific ant hosts. However, by studying *Ophiocordyceps unilateralis sensu lato*, recently discovered in North America, they showed that the fungus could kill any ant species it infected – but could only control the behaviour of those that it infects in nature. This suggests a remarkable co-evolution between the host and pathogen over many years. They carried out mass spectrometry to study the metabolites present in the secretome of the fungus when infecting the brains of several ant species. The fungus reacts differently to different ant species, through the variable excretion of metabolites upon infection. From the profiling of these metabolites Charissa identified two compounds - guanidinobutyric acid (GBA) and sphingosine, that were abundant in the brains of the ant species that the fungus encounters in nature. These two compounds have been implicated in neurological disorders and cancers and

are known to be excreted by other fungal species. They allow the fungus to recognise the brain of its host. Charissa attempted to inject these mind controlling compounds at a range of doses and combinations, but the ants did not exhibit the death grip behaviour. However, Charissa explains; "We weren't surprised that the injection of just these two compounds didn't lead to the death grip behaviour. It is rather a complex mixture of many compounds, acting together in a certain concentration that will lead to this complex manipulated behaviour". Ultimately, this is the first time that chemical compounds have been identified in this natural system and gives an important insight into the blends of chemicals that have evolved for such remarkable mind manipulation – and why they are important for species specific interactions.

In their natural environment colonies of ants, bees, wasps and termites often contain thousands or even millions of individuals living in high densities. Many of these species have evolved ways to deal with microorganisms that may attack the nest to reduce disease outbreak and new infections – known as 'social immunity'. Colony mates that detect an infected fellow carpenter ant will attempt to transport it away from the colony in order to reduce transmission. These previous investigations have concentrated on studying only the colony when it becomes infected, and often under laboratory conditions. In light of this Raquel Loreto and colleagues from Penn State University investigated the infection and transmission of *O.camponoti-rufipedis* when infecting Camponotus rufipes under field conditions.

Previous research indicates that the development of the Cordyceps fungus relies heavily on the microclimate – unable to spread when infected cadavers are placed on the floor or in the dry upper forest canopy. The fact that the infected ants reliably "death grip" to leaves in the understory vegetation, indicates that this behavioural control is adaptive for the fungus. This led Raquel and her colleagues to question whether Cordyceps can therefore develop inside the nest. In order to investigate, they collected the dome like carpenter nests – half of which were currently inhabited and half deserted – and placed them in buckets. Within these nests they placed newly infected and deceased carpenter ants and waited 10 days – the crucial time period needed for the fungal stroma to develop. But none of the ant cadavers developed to a reproductive stage – they were either removed by live ants, developed abnormally or did not develop at all. Simply being inside a nest, inhabited or not, wipes out the fitness of *O.camponoti-rufipedis*. The stroma is unable to develop

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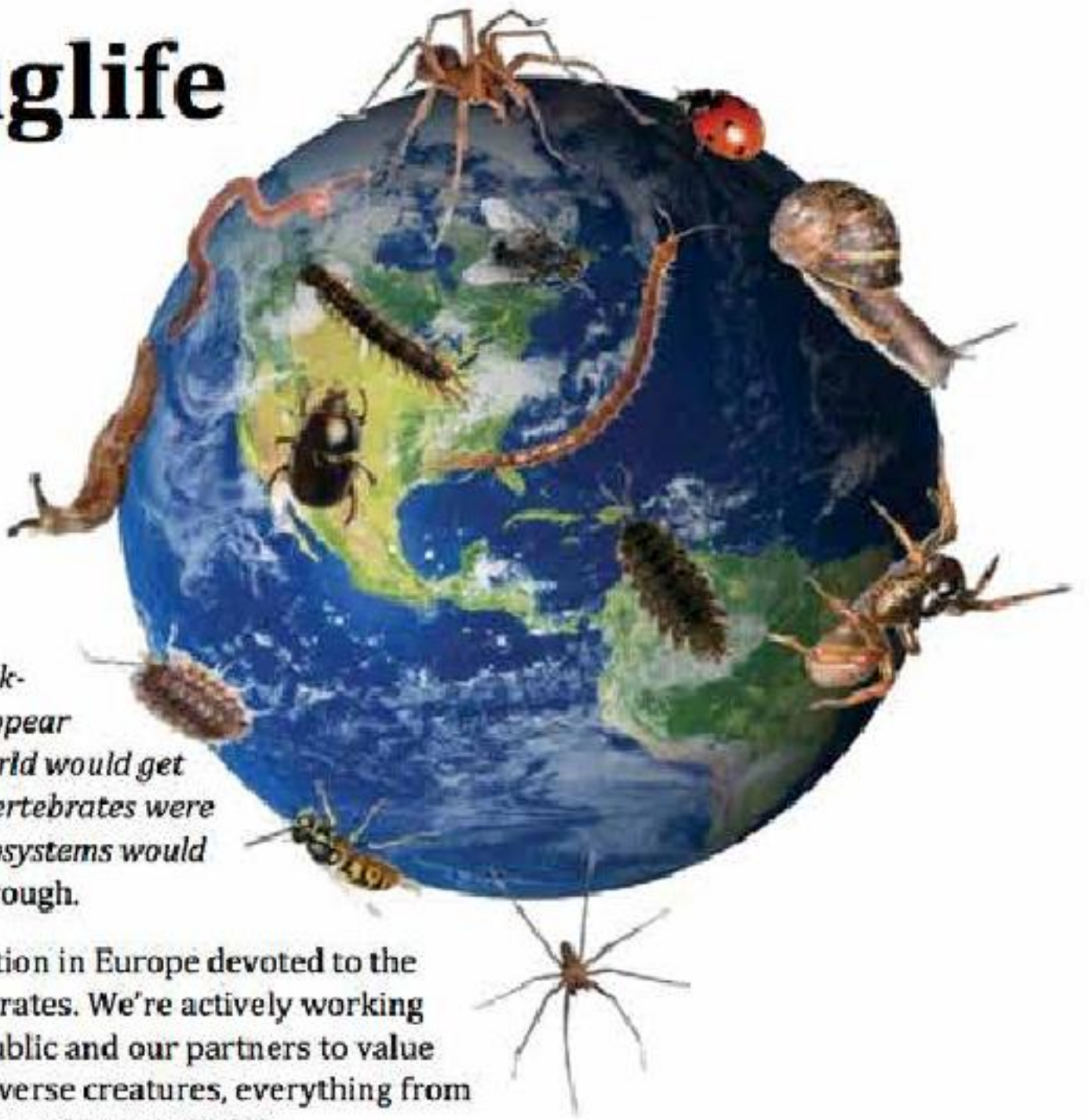

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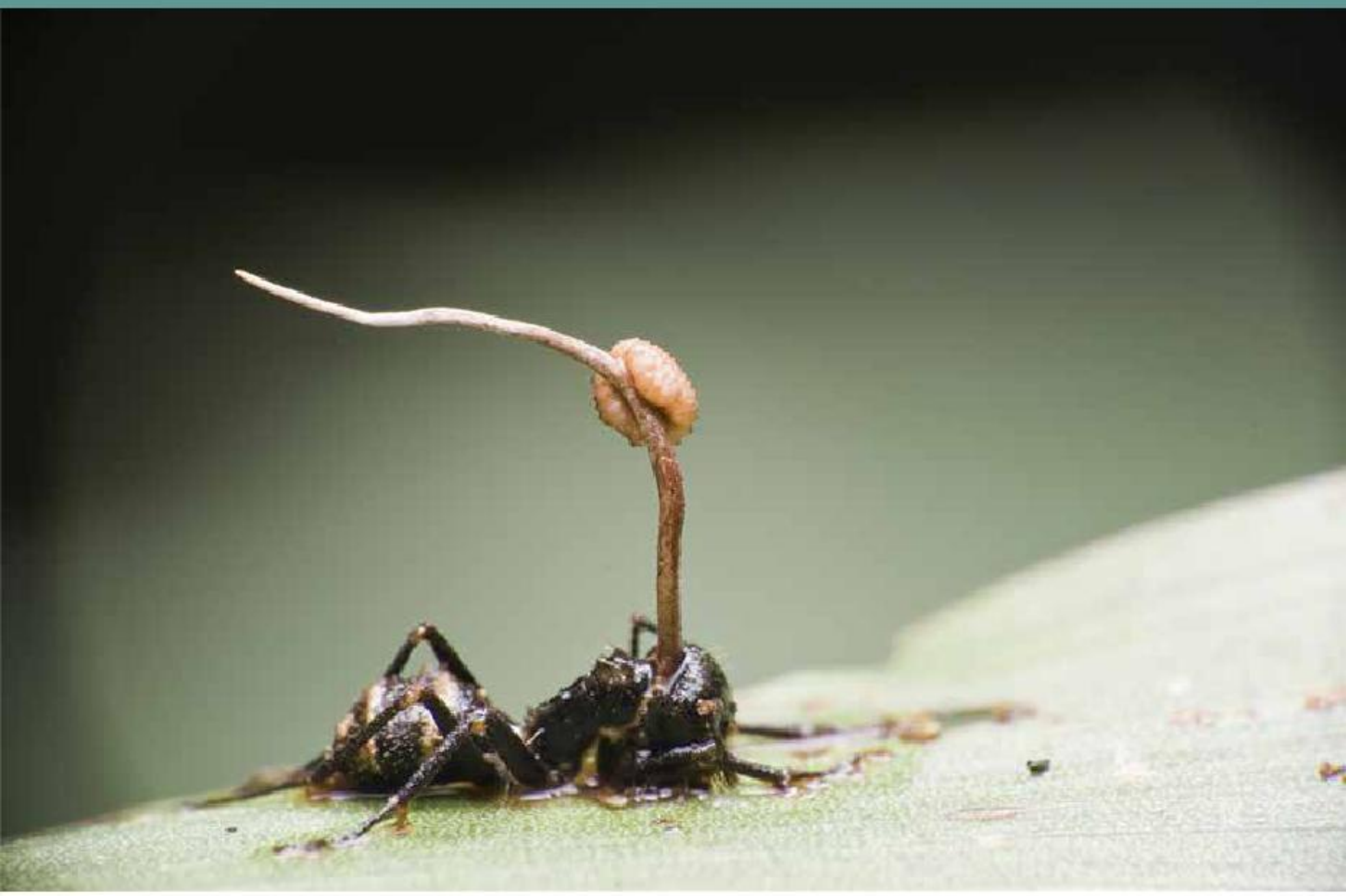

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in its usual perpendicular manner due to the constrictions of the earth, and the microclimate is not of a favourable condition. Even if it were able to develop – it is not advantageous for the fungi to grow where it might be removed and destroyed as it was most times from the inhabited colony – the first example of social immunity in ants under field conditions.

Next, in a longer 20 month study of 4 of these colonies the researchers mapped dynamics of the fungus by pinpointing the location of each infected cadaver. "We limited our survey to the immediate area surrounding the nest because this is the zone the ants must walk through to leave and return to the colony," Raquel said. "To better understand the path worker ants took, we measured and mapped in 3-D the trails formed by the ants, and that allowed us to determine spatial location of potential new hosts, which would be on the foraging trails."

By plotting the positions of the cadavers with respect to the nest and trails, the researchers established that infected ants die on the "doorstep" of the colony. Whether the inconvenient positioning of the dying ants is controlled by themselves or by the fungus – it certainly helps the fungus to spread. "What the zombie fungi essentially do is create a sniper's alley through which their future hosts must pass," David Hughes, leader of the research group, said. "The parasite doesn't need to evolve mechanisms to overcome the effective social immunity that occurs inside the nest. At the same time, it ensures a constant supply of susceptible hosts."

In their study area in Southeast Brazil the *C.rufipes* carpenter ant is abundant – 17 colonies existed and the researchers found that every one was infected with the Cordyceps fungus – with infected ant cadavers found surrounding each one. You might think then, that such a mind-controlling, specialised and deathly parasite might be a significant threat to all of these colonies. But despite its prevalence none of the colonies were observed to collapse, suggesting that infection is a chronic and long lasting occurrence – but a tolerable one.

These studies have started to unravel the chemical nature of compounds that are used to manipulate the brain in ants and to examine how parasites manipulate hosts in the field. These are both interesting in themselves, but they make me wonder about the microorganisms from which we sometimes find ourselves under attack. Humans as well as cats can be infected with *T. gondii*, a parasitic protozoa, which may induce increased aggression, jealousy and suspicion. Men also show more signs of risk taking behaviour and end up more likely to be involved in traffic accidents. This particular parasite infects up to a third of humans, implying that some of us could be acting rather strangely for the parasites' benefit. My question is; who is infected and who isn't? Who is truly behaving "normally" and to what extent are we and other animals all slaves to our parasite puppet masters?

Dr Robbie Rae is a lecturer in Ecological and Evolutionary Genetics at Liverpool John Moores University. He studies the genetics of host-pathogen interactions between nematodes and bacteria.

De Bekker, C., Quevillon, L.E., Smith, P.B., Fleming, K.R., Ghosh, D., Patterson, A.D. and Hughes, D.P. (2014). Species-specific ant brain manipulation by a specialized fungal parasite. *BMC Evolutionary Biology*, 14:166.

Loreto, R.G., Elliot, S.L., Freitas, M.L.R., Pereira, T.M. and Hughes, D.P. (2014) Long-term disease dynamics for a specialized parasite of ant societies: a field study. *PLoS One*, DOI:10.1371/journal.pone.0103516.

Say what?

Turns out animal communications aren't as simple as we originally thought.

Words by lead author Dr Arik Kershenbaum

Talking to animals. Surely one of the oldest dreams of humanity. Ever since humans began hunting, we have wanted - or needed - to understand the signals that animals give to each other. Legends abound with stories of animals in deep conversation with one another, or with their human protagonist - within fantastical worlds where animals are really just furry people, complete with a language and culture of their own.

But how much of this is pure wishful thinking? Do animals have language? What do they say to each other - if anything at all? These questions have preoccupied people from all walks of life - children and adults, writers and philosophers. But what is the scientific approach to this question? Can we even adequately define what language is, or whether animals communicate consciously - as opposed to a kind of instinctive response that is very different from our own self-awareness? Scientists are also interested in a related question: Where did our human language come from? Did it evolve from animal communication, and if so, how? Do we see a line of continuous variation, leading from simple, meaningless animal communication, right up to fully-fledged language?

In fact, we see absolutely no evidence of a gradual development of language, no animals with "half a language", nothing, in fact, that even approaches our human ability to communicate. Not even dolphins and whales - the most sophisticated vocalisers in the animal world, or our closest relatives the great apes appear to have any more than the most basic communicative ability.

So something is wrong with the way we understand the natural world: which is of course the most exciting challenge a scientist can take up! Either we are mistaken in our understanding of just how complex animal communication is, or we have failed to grasp the mechanisms by which language could have evolved. Or possibly both. But before we begin to explore these questions, it helps to have a clear definition of what we're looking for. What is language?

It's not easy to give a general definition of something when all we have to go on is a single example from our own species. How can we be confident that whatever definition we give won't be tailored to fit our own language, and would exclude other - perhaps very alien - forms of communication?

"A language has to be infinitely extensible. This is the true distinction between the communication of humans and of animals"

This isn't a trivial problem, but scientists have tried to identify some of the essential components that should be present in any language, whatever species it comes from. Three criteria in particular stand out.

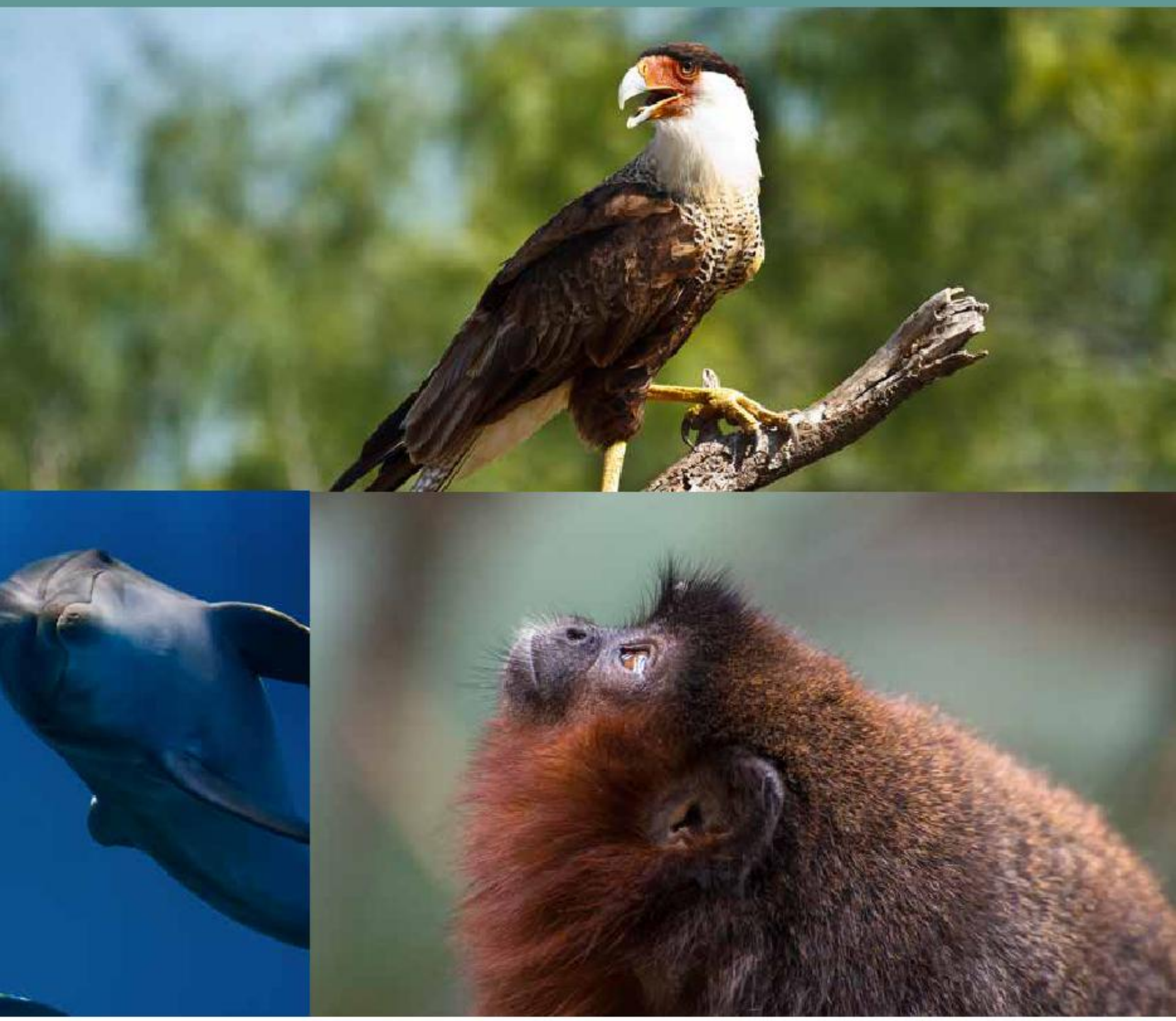
Firstly, a language should be learned. That is, any instinctive form of communication isn't really a language. We observe not only that human babies develop language as they grow; also some animals such as dolphins and birds are not born with their communication repertoire, but develop it with experience. However, the main reason to constrain a true language to be learnt, rather than instinctive, is that it's hard to imagine how an individual could be born knowing more than a small number of words or concepts - certainly not the tens of thousands of words that an average adult human is familiar with.

Secondly, a language should say something about the world around us. Many birds (and other animals) sing complex songs that advertise their own prowess, or mark their territory. However, this isn't considered language, because it's independent of the environmental context - it only gives one message, no matter what is happening to the animal, or to others around it.

Finally, a language has to be infinitely extensible. This is the true distinction between the communication of humans and of animals. We can (in theory) express any concept, from a child's first purposeful words, right up to the complete works of Shakespeare. While many animal species fit the first criterion of a learned communication system, and some fit the second of contextual meaning, none that we know of has the ability to combine sounds in a way that can represent such a wide - potentially infinite - range of ideas. Humans achieve this through grammar - a set of rules for combining symbols (or sounds), which give meaning to the structure with which the symbols are combined. "He is a good dog" has a different meaning than, "Good he is a dog", despite only one word having been moved.

It is the question of grammar that most differentiates between all animal communication and human language. We have so far failed to find any significant use of grammar in the animal world - although we are still looking hard. The most sophisticated grammar users (outside of humans) that we know of are found in some group-living monkeys. The putty-nosed monkey uses different call types to warn of the presence of different predators: a "pyow" call for a leopard, and a "hack" call for an eagle. However, when these two calls are combined ("pyow-hack"), the meaning is completely different: a signal for the group to move on to a new location. A related species, the titi monkey, uses call combinations in a different way. Titi monkeys produce 'A' alarm calls in response to eagles, and 'B' alarm calls in response to oncillas - a kind of jungle cat. But when they spot an eagle on the ground, titi monkeys intersperse some 'B' calls with their "eagle" warning, and if there's a cat in the tree, they intersperse some 'A' calls with their "cat" warning. This combination of different elements to produce different meanings is about as sophisticated as any animal grammar that we know.

You could be forgiven for being a little disappointed. Is that the



best animals can do? We scientists can get a bit disappointed too. How could we possibly explain the evolution of language, when the closest thing we observe in the animal world is "cat in a tree"? What about dolphins and whales? Perhaps they have a more sophisticated grammar that allows them to communicate complex concepts?

Perhaps so, as dolphins in particular have many of the characteristics that you would expect to lead to the development of language: they are highly intelligent, they live in a very acoustic environment, live in groups, and even more importantly, they cooperate in tasks such as catching food. Dolphins even learn at least part of their vocal repertoire, and use specific sounds in particular contexts, even using personal "names" to refer to each other. Unfortunately, we are only beginning to scratch the surface of dolphins' communication vocabulary. Unlike birds, monkeys, and other land animals, dolphins and whales don't seem to divide their vocalisations into discrete "notes" - probably because unlike land animals, they don't need to take a breath in between sounds. Scientists are still struggling with dividing up those continuous trains of whistles and clicks into relevant units; either separate sounds that are combined together to give different meanings (phonemes), or sounds that have distinct meanings themselves (morphemes).

So if we know so little about what really underlies animal communication, what promising avenues for future discovery are there? Much of the work in uncovering the secrets of language involve detailed mathematical analysis of the structure of communicative sequences, in an attempt to identify the fingerprints of grammar, purposeful organisation, or meaningful content. Scientists at SETI - the Search for Extra Terrestrial Intelligence - have even proposed that there are some mathematical patterns that would be expected in any language of any origin from any species (or planet), and have been searching for such patterns both in cetacean communication, and in signals from outer space. Another approach is to look at how random patterns in vocalisations may have evolved slowly into purposeful grammar. Randomness is abundant just about everywhere you look in nature - including in animal

vocalisations. Some birds and mammals sing what appears to be a totally arbitrary sequence of notes, without any pattern or structure. But even random sequences can have different levels of complexity in the rules that generate them. In the very simplest system (known as a regular grammar), each character in a sequence depends only on the few immediately preceding characters. Such systems can never generate the kind of infinite extensibility that seems to be fundamental to language. More complex sets of rules (known as super-regular grammars) are capable of representing even long and complex ideas, by using recursive structures, for example phrases within phrases ("The rabbit, eating a carrot under the tree, is looking at me"). Computational linguists have long felt that recursion, through super-regular grammar, is a condition - perhaps the condition - for the definition of language.

One of the big questions in animal communication research then is; are there any animals that generate vocal sequences using a super-regular grammar? So far, no one has been able to show convincingly that such a thing exists, and so we are left, as we began, with humans being the sole example of a linguistically capable species. What is more, it has been difficult to come up with a convincing evolutionary explanation of how a regular grammar could have morphed slowly into a super-regular one, as the two are quite strikingly different, and probably require quite different neural structures.

> "You could be forgiven for being a little disappointed. Is that the best animals can do?"

In our recent research though, we didn't look for super-regular grammar in animals; instead we went back a step and looked for regular grammar. Most researchers have assumed that animals without a language must be using a regular grammar - the simplest of the simple possible ways to construct vocal sequences. We looked at long vocal sequences from several different species,

cetaceans (pilot whales and killer whales), birds (chickadees and finches), and land mammals (hyraxes and orangutans), and tested how likely it was that they were generated by a statistical process known as a Markov process - a mathematical equivalent to a regular grammar. But we also tested these sequences against other possible random sequence generators, including one known as a renewal process, which has certain properties in common with super-regular grammars. In particular, with a renewal process, subsequent characters don't depend just on the immediately preceding ones, but the sequence can be influenced by characters that occurred arbitrarily long ago - a property that in some ways resembles recursion.

Surprisingly, we found that not one of the species we examined produced sequences that seemed to match the Markov process, and many of them seemed much more similar to a renewal process. So while these non-linguistic animal vocal sequences still appear to be random, they do have some unexpected statistical properties that tantalisingly hint at a potential for more complex grammatical structure.

Does this mean that these animals have a proto-language? No, there's no indication of this. However, we raise the interesting possibility that perhaps the evolution of language may not have needed to bridge that huge gap between regular and super-regular grammars. It seems that many animal species generate vocal sequences that are quite random, but still possess the underlying properties that could have been built upon by evolutionary forces to generate more complex grammatical relationships. As early hominids evolved, becoming more social, more intelligent, and as their brains grew dramatically, these anatomical and social changes could have made use of the complex randomness of their communication, providing the framework for the sudden and spectacularly successful development that makes us unique - language.

Kershenbaum A., Bowles A.E., Freeberg T.M., Jin D.Z., Lameira A.R., Bohn K. (2014) Animal vocal sequences: not the Markov chains we thought they were. Proceedings of the Royal Society B

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Smells like home

Corals and fish respond to chemical cues to sense damaged reefs, and pick the healthier ones. Words by Kirsty MacLeod.

If you were to picture a coral reef, you might picture the familiar image of the shrinking periphery of the Great Barrier Reef, bleached pillars of coral, and sad, grey seabeds. It is no secret: coral reefs are in trouble. As a common symbol of environmental doom and gloom, it is almost easy to forget how gorgeous they are: underwater carnivals of riotous colour, a pulsing and lively interaction of creatures you couldn't make up. The first Google image collection when searching for "coral reefs" is titled "Beautiful". Tellingly, the fourth is "Damaged".

Corals, the foundation species of the reefs, are chronic victims of pollution, over-fishing, and climate change, making them a veritable barometer for anthropogenic damage. Resultantly, coral cover has declined a staggering 80% in parts of the Caribbean, with a similar story throughout the Pacific. Decades of research have gone into trying to understand not just the reefs and their complex multi-level societies, but how they respond to change, and what we might do to try to restore them. Reef restoration projects have aimed, with varying levels of success, to reverse the shift from dominance of the reefs by corals to dominance by seaweeds in degraded areas. What has been missing thus far is an understanding of what exactly suppresses corals in degraded sites, what facilitates the domination of seaweeds, and how this cycle perpetuates.

> "Chemical cues act like a language for coral reef systems"

A study recently published in Science may have finally found a missing piece of the puzzle: juvenile corals and fish are repelled by chemical cues produced by seaweed, and attracted to cues produced by healthy reefs. In short – degraded reefs are bad real estate, and reef species aren't buying it.

Dr. Danielle Dixson, who led the study, did not have the classic

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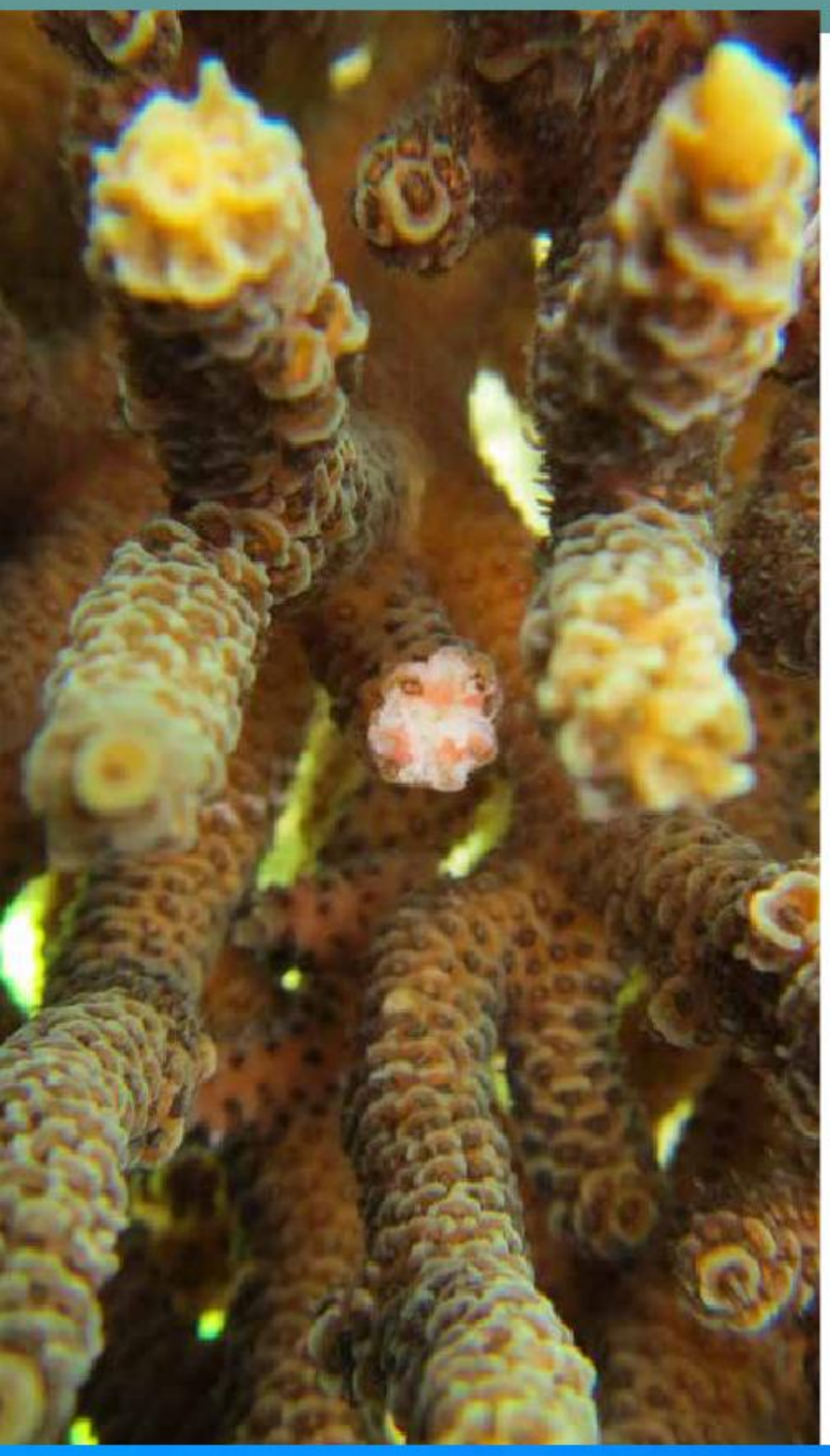


rock-pooler's background one might expect of a marine biologist. "I grew up in the mid-west of the United States," she says, "nowhere near the ocean or coral reefs!" Nevertheless, she was not immune to the technicolour lure of coral reefs and the creatures they harbour, proclaiming after a childhood visit to the aquarium that she wanted to be a marine biologist. "My early exposure to science made a big impression on me", she says. Now she is an Assistant Professor at Georgia Institute of Technology, mainly working on marine species interactions and behaviour - for which coral reefs provide a perfect system.

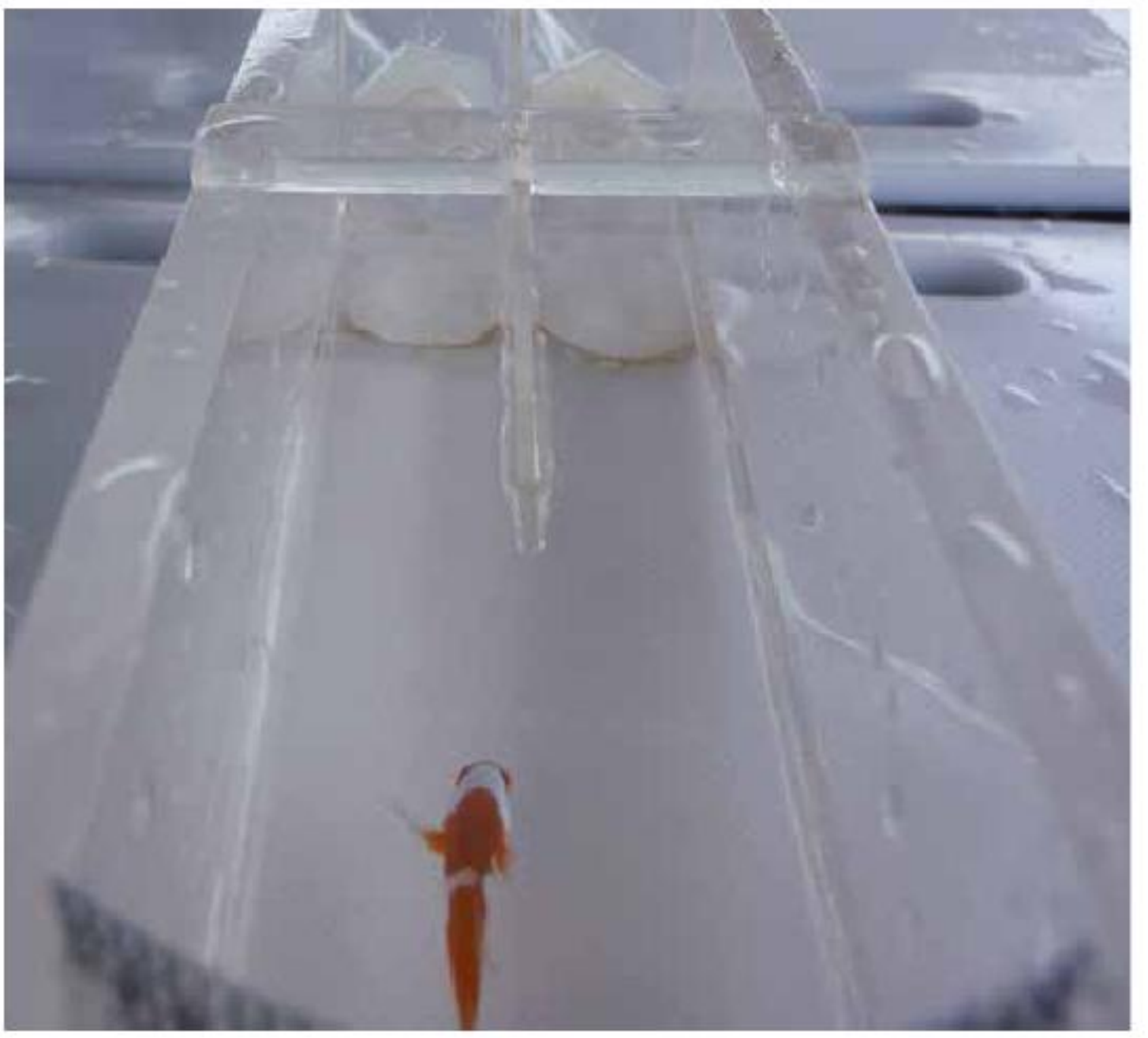
Danielle's PhD thesis investigated the influence of chemical cues on how coral reef fishes select settlement sites. "Chemical cues act like a 'language' for many coral reef organisms," Danielle explains. Able to dispel long distances, they provide valuable information about habitat quality by acting as a snapshot of the recent species composition of a site. The natural next step in her research was to look at how habitat quality might influence where coral and fish juveniles choose to settle. The settlement behaviour of juveniles is of paramount importance, as this predicts future population success and is therefore a key indicator of restoration potential. This research would answer a crucial question in reef restoration: what could be limiting reef recovery – differential survival of corals and fish on degraded versus pristine sites, or some aspect of coral and fish behaviour?

To answer this question, Danielle - by then a post-doc in the lab of Professor Mark Hay, senior author of the study - travelled to Fiji where, she says, "the reefs are unique." Dotted around Fiji are over 250 locally-managed Marine

Protected Areas (MPAs), covering a total of nearly 11,000 square kilometres where fishing is not permitted, set up as part of a commitment made by the Fijian government in 2005 to protect 30% of its waters by 2020. "It is not common to have reefs that are so healthy, with high benthic coral cover, directly adjacent to an area with very little coral cover and high levels of seaweeds," she explains. Taking advantage of this striking dichotomy between non-fished MPAs and fished non- MPAs, Danielle and her collaborators set up an experimental system to test how coral planulae and juvenile fish responded to chemical cues from water from areas of different habitat quality, both in the lab and in the field.

Coral planulae, the free-swimming larval form in which coral disperse and settle, are capable of complex responses due to cytological and biochemical sophistication – could they be able to interpret the language of chemical cues and make adaptive decisions about where to settle? To answer this question, Danielle and her team first offered planula larvae of Acroporid coral species a choice in the laboratory: they could move toward water collected at the centre of an MPA site, or toward water collected from a fished, non-MPA site. All larvae preferred water from Marine Protected Areas. Further work showed that this preference was due to the presence of cues in this water released by healthy corals and crustose coralline algae, indicative of healthy reefs. In contrast, chemical cues from seaweed present at non-MPA sites (cues including coral-damaging allelochemicals) repelled coral larvae, resulting in reduced inclination towards non-MPA water.

Importantly, they saw the same results when they took their experiment to the field: clear preferences for chemical cues abundant in healthy reef systems. Danielle found the matching of lab and field results particularly exciting. "Often when you run experiments in the lab you are excluding so many variables that they do not always transcend to the field," she says. "In



this project, the laboratory and field results mirror each other perfectly." Even more convincing was the consistency between the results for coral larvae and for juvenile fish. The preference experiments were repeated using juveniles of 15 reef fish species, which showed remarkable abilities to discriminate between chemical cues. Fish showed overall preference for coral cues, and a further increased preference for cues from sensitive species that would not be found on unhealthy or degraded reefs.

The conclusions were striking: coral larvae and juvenile fish are able to collate complex information about habitat quality through chemical cues, and make adaptive decisions about whether and where to settle, an important advance in the study of coral and reef fish species' dispersal behaviour. Even if anthropogenic damage to degraded reefs can be mitigated, this study suggests further barriers to be overcome for reef management and restoration: the preference of fish and coral juveniles for non-degraded reefs.

Despite the challenges their study indicates for reef restoration, Danielle believes that finding out this piece of the puzzle is a positive step: "It is important that we understand the information being used in order to effectively manage the marine system." She also believes that it highlights room for improvement too. "I think that the take home message of this study is that MPAs are effective tools at protecting inhabitants, but in some areas such as Fiji when there is a disjunction between the habitat quality of MPA and fished sites, MPAs may not be enough," she says. "In these locations additional efforts are necessary to increase recruitment to the fished area which may no longer be deemed as good habitat for incoming larvae."

Alasdair Edwards, Emeritus Professor of Coral Reef Ecology at Newcastle University, agrees that the results highlight where reef restoration efforts may be going wrong. "When most people think about 'reef restoration projects' they tend

to envisage active restoration interventions by humans, usually involving transplanting corals to degraded reef areas," he explains. "There has been little successful 'active' restoration of coral reefs at any significant scale so far and what these results show potentially makes things harder." The striking preference of coral larvae and fish juveniles for non-degraded reefs shown by this study could have practical applications for other methods, however. "The work of coastal managers who try to manage deleterious impacts on reefs tends to be overlooked as less sexy but their 'passive restoration' efforts provide the foundation to reef restoration at any meaningful scale. Managers need to think more about seaweed removal (or herbivore enhancement) as part of these 'passive restoration' efforts, now that certain seaweeds are being shown to be an even greater impediment to natural recovery than previously thought."

It may seem that the more we find out about coral reef systems, the harder it appears to reverse the damage already done to them. This study "reinforces that we are dealing with complex systems that we do not yet fully understand," says Alasdair; "thus, our restoration efforts, although well-intentioned, are somewhat naive." One unmitigated positive from the study is the obvious effectiveness of Marine Protected Areas in Fiji in protecting reefs within their borders, which Danielle attributes to "local communities putting a tremendous amount of effort into protecting the coral reef habitat." As is commonly the case, prevention is likely to be more successful than a cure. Dr. Madhavi Colton, Lead Conservation Scientist for the Coral Reef Alliance, agrees. "We're already tackling many underlying causes of reef decline by addressing overfishing, water quality, and other threats at sites around the world. Once coral reefs are fully degraded, it's really hard to get them back. So let's continue working to keep them healthy."

Kirsty MacLeod is a post doctoral researcher within the Zoology department at the University of Cambridge.

Dixson, D., L., Abrego, D. and Hay M., E. (2014). Chemically mediated behavior of recruiting corals and fishes: A tipping point that may limit reef recovery. *Science* Vol. 345 no. 6199 pp. 879-880. DOI: 10.1126/science.1258556

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Among the wildlife wonders to be found on Madagascar, the Madagascar pochard is easy to overlook. Yet this nondescript bird does have one serious claim to fame: it might be the rarest bird in the world.

In 2006, the Madagascar pochard *Aythya innotata* was reclassified as 'possibly extinct' on the IUCN Red List. Despite several searches, nobody had seen one in the wild since 1960. Then a team from the Peregrine Fund set off for a scarcely-visited part of the country to survey for Madagascar harriers. They were aiming for a village named Bemanevika and a group of small lakes shown on maps dating back to the French colonial era and not updated since. They did find harriers, along with several other endangered birds of prey such as Madagascar serpent-eagles and red owls. They also spotted some ducks. It was the team leader - Lily Arison René de Roland, a keen birdwatcher, who knew exactly what they were and the significance of the find.

Previous searches for the pochard were looking in the wrong place. Anything published before 2006 will say that the pochard's range is limited to one lake - Alaotra. There had been sightings elsewhere, mostly near the capital city of Antananarivo, but only on Alaotra were pochards seen regularly and in large numbers.

Now, here was a population of pochard 300km north of Alaotra. The total population was tiny, just over 20 and confined to a single lake called Matsaborimena. Tiny populations are highly vulnerable, not only to major environmental events such as cyclones, but also random changes in birth and death rates and the gene pool. With very little information to base a decision on, it was safest to assume the worst: this tiny population was highly vulnerable to extinction. Some way of preventing this was needed.

Three conservation charities got together and in 2009 a team was sent to Matsaborimena where they collected 22 eggs from three nests. The eggs were hatched in battery-powered incubators at the side of the lake and the chicks transported to the nearest town – a slightly unconventional method required because it was unlikely that eggs, even heavily padded, would survive Madagascar's terrible roads. Five years later and a specialist captive breeding facility has been built, local staff trained in avicultural techniques, and the captive pochards have started breeding.

This gave us time to find out more about these birds. Nobody had studied the pochard before, so our first question was pretty basic: what does a Madagascar pochard need to survive? Related to this, how well is this population surviving? Finally, why does it now occur in just one small area? Answering these questions would involve studying the wild population. With fewer than 30 birds to work with, the only way to proceed was as cautiously as possible – anything that might disrupt or disturb birds was ruled out. This meant no experimental work and some observational techniques were also avoided. For example, we wanted to know about dispersal – how often and how far the pochards moved from their lake. But there are no methods for attaching transmitters to diving ducks that are not either problematic for the duck (such as harnesses, which inhibit swimming underwater) or just hugely invasive (anchoring the transmitter under the skin has been successfully used on more common diving ducks but requires an operation). As technology improves and devices get smaller this problem might go away, but for now we're stuck with unmarked birds. Mostly, we spent a lot of time standing at the edge of the lake with telescopes, watching.

"The total population was tiny... and confined to a single lake"

Studying their diet was problematic. Pochards are diving ducks, meaning they dive and collect food out of sight

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on the lake floor. Unable to simply record their foraging intake, we started by surveying the lake floor to see if there was anything down there that pochards might find appetising. This revealed a very limited menu for the pochards.

Next, we collected faeces and feathers. I have there glossed over a problem, which is that pochards spend most of their time on the water, and faeces do not float. Small wooden platforms, which the pochards liked to rest on, were the solution. The feathers were for stable-isotope analysis, which involves measuring the composition in your sample of non-decaying isotopes of an element. Here we were interested in nitrogen. A heavy isotope, 15N, is favoured when proteins are assimilated in the digestive system, the upshot of which is that 15N concentration increases as you go up trophic levels. In fact, it increases by a fairly predictable amount so by comparing feathers with potential food, we can tell roughly what the pochard was eating when it grew that feather. These pochards eat only insects - unusual for a genus in which most species are omnivorous.

The pochards' breeding behaviour is fairly typical for diving ducks. They build nests in the papyrus marsh that surrounds the lake and lay clutches of nine eggs on average. Genetic analysis of the captive birds revealed that extra-pair copulations and egg-dumping (females laying eggs in other pairs' nests) are common behaviours, meaning that a single nest will represent more than two parents – excellent news for our captive population, leaving it with far more genetic diversity than you might expect from just three nests. Overall, we concluded that these are fairly typical pochards with no hugely specialised habitat requirements - more good news.

The first ever captive born Madagascar pochard, named Voholany

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But then we spotted a problem. Whilst nearly all the eggs were hatching, just 1 in 20 chicks survived to be fully grown. Ducklings of most species suffer high mortality rates, particularly in the first days after hatching, but the rates for our pochard seemed worryingly high. Unusually, the mortality rate was higher in two week old chicks than newly hatched ones - indicating that they succumb to starvation caused by living in less than ideal habitat. The lakes at Bemanevika are volcanic crater lakes, and typically are deep with steep sides and no shallow areas. Diving through water is energetically demanding, even for a creature adapted to it, and young chicks are weak swimmers. In experiments, common pochards will choose a poor food source 1 metre deep over a rich source at 2 metres - as the former provides more energy overall. At 2 metres, Matsaborimena lake is simply too deep. The adults get by, but the chicks simply cannot gather enough food.

If it's not good for them, what are they doing there and nowhere else? To answer this, we went on a tour of Madagascar, visiting as many wetlands as we could. Each site was surveyed to see if pochards could survive. At every single site we visited the answer was no.

The deforestation the country is suffering is well known, with 90% of the forests gone, but this has overshadowed other problems including those suffered by wetlands. Deforestation does not help because, with nothing to hold it together the soil washes away during frequent heavy rain, ending up in lakes and rivers where it smothers the lake floor. The forest cannot regenerate, as the land is burned every year. Many reasons have been suggested for why the Malagasy burn their land and sometimes the Malagasy themselves are not even sure. After several years in the country I wonder if people just like starting fires – the extent of burning at the end of each dry season has to be seen to be believed.

Next, the marshes surrounding the wetlands are cleared. The cause of this is more obvious: the Malagasy love rice (it is the basis of every meal, including breakfast) but the farming methods they use are basic. There are no elaborate terraced paddies here, and instead rice is simply grown in places that are naturally wet enough. This means marshes, from which the natural vegetation first has to be cleared. The rice may be sprayed with pesticides, further polluting the lake. Finally, there are exotic fish, which were introduced in an attempt to provide a source of protein.

These fish, including tilapia and carp, eat the insects that the pochards rely on. Further, diving birds can get tangled in fishing nets and drown. It is hard to blame the Malagasy people for any of this. In one of the poorest countries in the world most people are subsistence farmers, depending on crops, cattle and fish for food, and on collecting wood for fuel and building.

This was the story we found at every wetland, so it is not all that surprising that the pochard nearly went extinct. Alaotra was among the last wetlands to be destroyed. The first Europeans to visit it in 1874 report an almost pristine lake, while other wetlands were already turned over to agriculture. The pochard may have once been widespread, but by the time the first Europeans got to Madagascar and wrote down what they saw, the pochard was already confined to Alaotra and a few other sites that these early travellers never visited. Matsaborimena, meanwhile, has been kept pristine by a fortuitous set of circumstances. The lake is too deep for rice farming and, 1,600m above sea level, also too cold, meaning few people have ever settled here. This in turn means there is plenty of forest, and exotic fish were never introduced. Pochards cannot thrive here but they do exist, which still makes it better than any other lake in Madagascar at the moment.

This is not unique in the conservation of rare species. By the end of the 19th century, red kites were confined to a tiny area in central Wales - but breeding success was low due to a lack of food. They survived here because this was the only site in the UK where they were not persecuted. Once these threats were largely removed, reintroductions elsewhere have been very successful - illustrating what might be needed to help our pochard. Reintroductions are notoriously difficult requiring removal of the factors that drove localised extinction to begin with. Given the whole suite of problems faced by wetlands in Madagascar, this will be a huge task and will ultimately mean restoration of a lake. But we have chosen a site, and are working with the locals to start the long process of restoring it. Crucially, this should also make the lake better for people too, by providing cleaner water and healthier fish populations, and it is this that gives us optimism that the project will work.

Bamford, A.J, The Seing, S., Razafindrajao, F., Robson, H., Woolaver, L.G., and Rene de Roland, L.A. (2014) The status and ecology of the last wild population of Madagascar Pochard Aythya innotata. *Bird Conservation International*. doi:10.1017/S0959270914000033

"They cannot thrive but they do exist"

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Without a need to taste sweetness, ancient birds lost the gene that detects it. But hummingbirds are different - did they get the gene back?

Words by Miranda Walter

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"The ability to taste sweetness was lost on them - and so they lost it."

In 2004, the first avian genome - that of the chicken - was fully sequenced. Among various key discoveries were those concerning the sensory system - critical for determining responses to the environment and consequently, survival. The original genome sequence highlighted that the chicken may have lost the ability to taste bitterness. Soon after, new research uncovered that the chicken was missing a vital genetic subunit – T1R2. Chickens, it appeared, could not taste sugar.

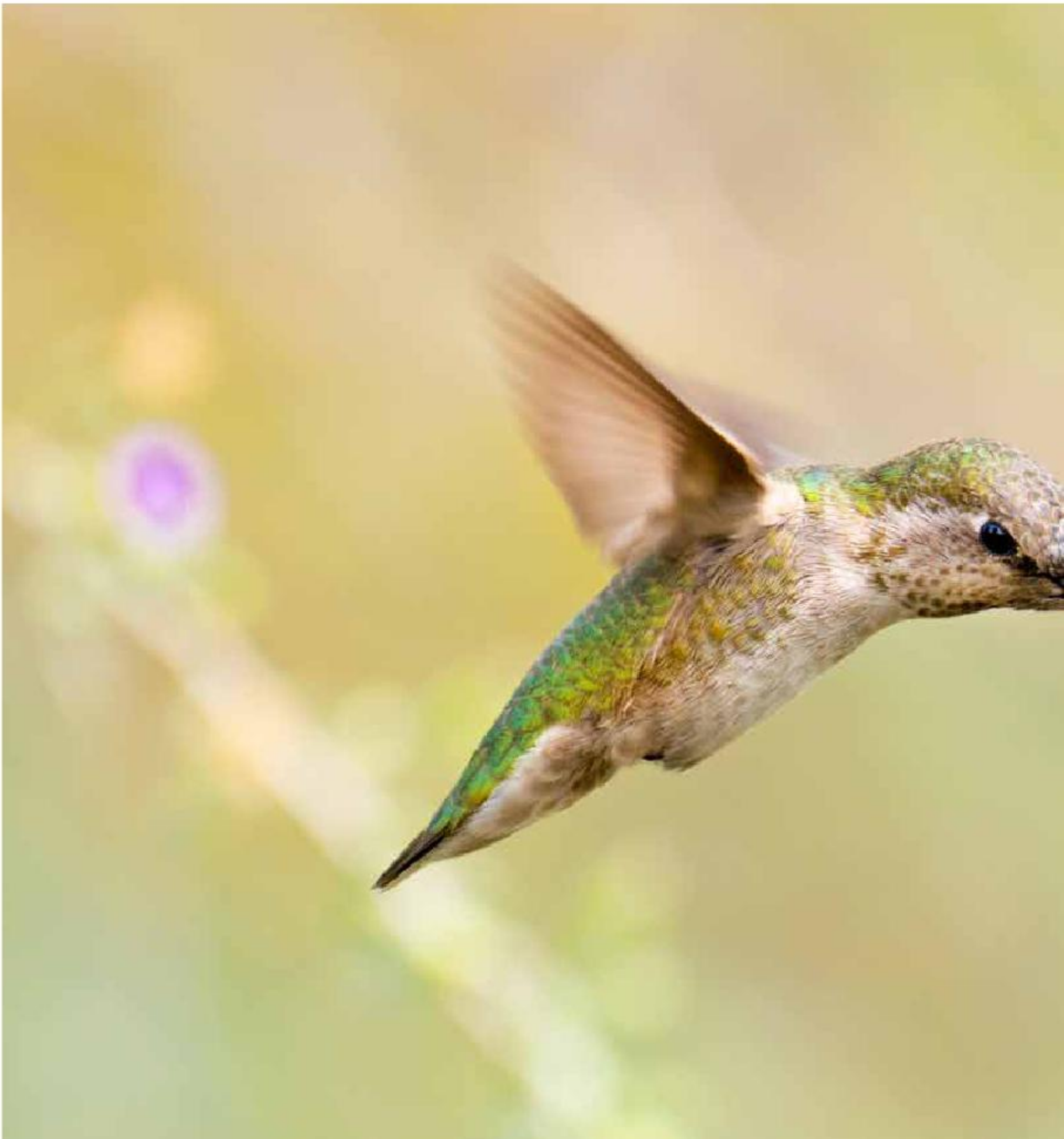
Maude Baldwin of Harvard University has now discovered that chickens aren't the only birds to have lost the ability to taste sweets. She compared 10 bird species genomes from across the evolutionary tree including finches, falcons, hummingbirds and mallards - possessing a wide variety of diets. The results confirmed that indeed, the original gene for sweet taste perception - T1R2, was absent in all of them.

We all know from sugar highs and lows that it is a valuable resource. Why would the ability to detect it be lost? "It is hard to know" explains Maude, "one idea is that maybe it was lost originally due to the diet of the ancestor birds." These ancestors were a highly carnivorous lineage of dinosaurs called theropods. "Many mammalian carnivores don't have T1R2-- there appears to be relaxed selection on the sweet-receptor in meat-eaters." Birds therefore join ranks with a wide variety of predators including cats and hyenas that are indifferent to the sweet stuff. Whilst this would be a great shame to you or me, the ability to taste sweetness was lost on them - and so they lost it.

There are other possible explanations for the loss though; "bird genomes are smaller than mammal genomes and the gene families have fewer members —so maybe it got lost for non-diet related reasons as part of a general streamlining of the genome. There's no way of knowing!" Maude adds.

The bird species Maude analysed represented a diverse selection from across the evolutionary tree of life. The fact that none of them possessed the T1R2 subunit is likely representative of the whole Class. Why then, do the nectar-feeding family of the hummingbirds drink up to twice their weight in this sugary snack a day? "It was a clear question, but for technical reasons was harder to answer than we expected" Maude told me. Hummingbirds belong to the Trochilidae family and there are approximately 340 species that originated in the New World, some of which are among the tiniest bird species on earth today. Maude's recent research into this particularly diverse family of birds discovered a huge genetic leap that may have given rise to this whole family's existence. She and her team constructed a comprehensive study using both wild and captive species of hummingbirds to establish just how these little birds are lucky enough to taste sweet nectar.

Most vertebrates possess three genes; T1R1, T1R2 and T1R3 - responsible for building taste receptors of the same name. Taste receptors in vertebrates are protein receptors known as G protein-coupled receptors (GPCRs). These bind to the amino acids or carbohydrates from food and transmit signals to activate cell processes so that the contents of the food can be broken down and used. The T1R2 subunit recognises carbohydrates – the receptor that has been absent in birds and many meat eaters. The other two subunits T1R1 and T1R3, are coupled into a



Female Anna's hummingbird ©Birdiegal, next © Phoo Chan/Shutterstock

heterodimer to act as a receptor that recognises amino acids - an 'umami' taste receptor – or the receptor for 'savoury' foods. Without T1R2, T1R1-T1R3 was all that birds were left to work with in order to taste sweetness, but how?

"We had a hypothesis that maybe T1R3 was working alone to respond to carbohydrates as a 'homodimer' because some studies in cell culture from mammals had suggested that at very high concentrations, T1R2 might not be necessary. An alternative idea we had was that the T1R1-T1R3 pair had changed function, but this was just a guess"

Maude's team isolated each T1R subunit and tested their responses to carbohydrates. No carbohydrate recognition was observed in the hummingbirds using T1R1 and T1R3 separately, but together it responded to sucrose, fructose and glucose. The conclusion was drawn that the T1R1-T1R3 receptor is an obligate heterodimer, meaning it functions only when coupled together in the hummingbird. T1R1-T1R3 cells of chickens and swifts failed to respond to carbohydrates in the same way, instead responding to savoury compounds including alanine - an amino acid. What was just a guess therefore turned out to be a pretty lucky hunch. Their research shows evidence that ancestral savoury 'umami' receptors have been 'repurposed' via genetic mutations in the last 42 to 72 million years to become sweet receptors in hummingbirds. It is a modified version of the

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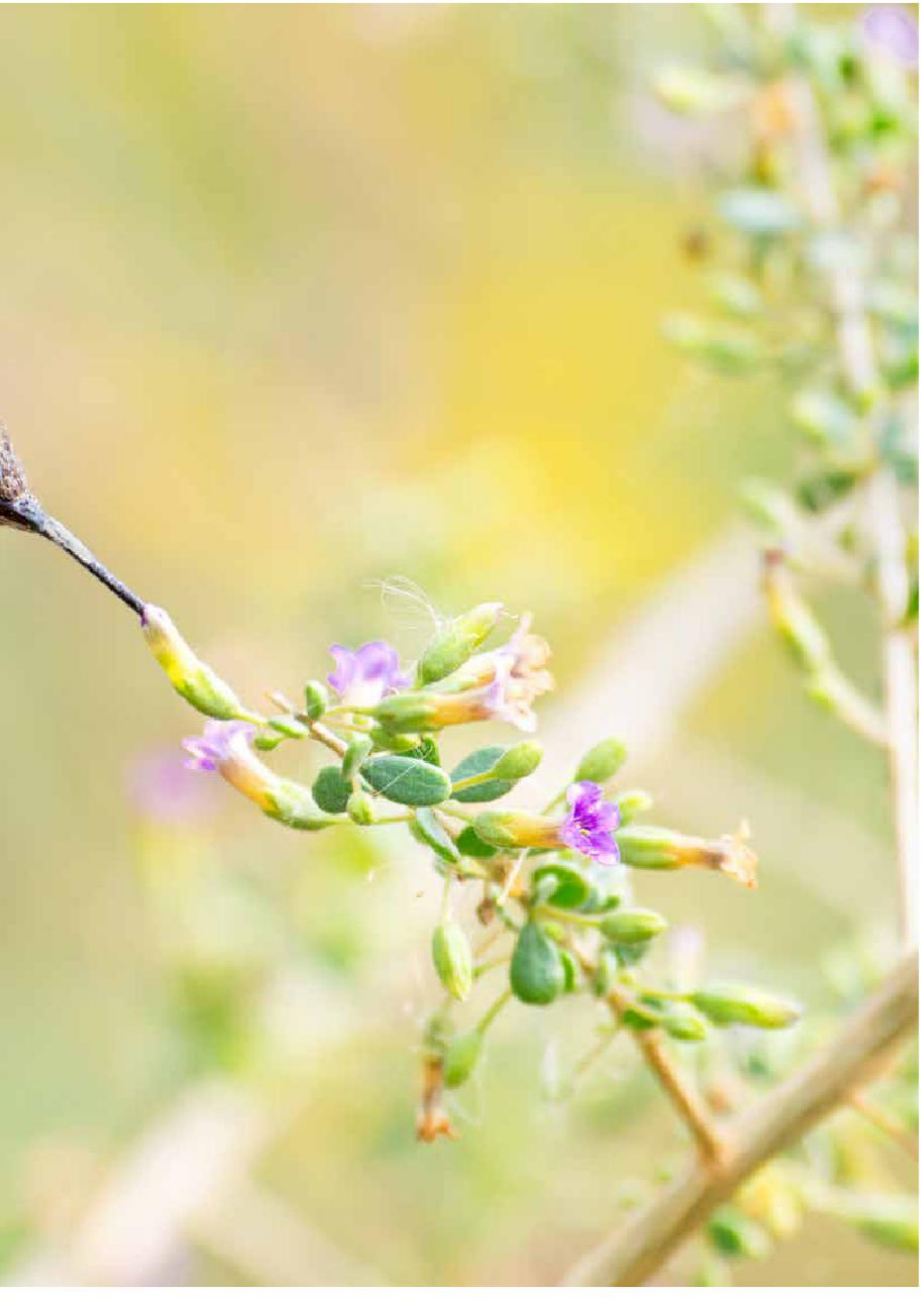

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T1R1-T1R3 receptor that gives the hummingbirds their sweet tooth, facilitated by surrounding sites of DNA whose proteins aid the sugar receptors.

For Maude and her team it was essential to identify what exact components made the distinction between savoury and sweet receptors given the heterodimer molecule T1R1-T1R3 was apparently the same receptor between the species. By making several chimeras - fusing parts of hummingbird T1R1-T1R3 genes with chickens' - they identified an area outside the cells called the 'venus flytrap domain' where the food molecules bind to the taste receptors, as the determining feature of this divergence. When the T1R3 venus flytrap domain of a chicken was inserted into the T1R3 of the hummingbird, the taste receptors bound to amino acids rather than sugars. When amino acids from the hummingbird T1R3 were reintroduced into the chicken T1R3 venus flytrap, sugars bound to receptors. Specifically, they identified 19 amino acids within T1R3 that were needed in order to tune T1R1-T1R3 in to sweet reception. Further chimeras showed that both subunits of the T1R1-T1R3 receptor must have evolved, as a combination of chicken T1R1 and hummingbird T1R3 did not respond to sugars, suggesting both subunits in hummingbirds mutated widely to enable sugar binding.

Maude then wanted to know what this meant for the actual hummingbirds beyond their genes and in the field. Unlike animals, humans are constantly trying to reduce their calorie intake – adding artificial sweeteners like aspartame to fizzy drinks in order to lower the nutritional value. Maude offered Anna's hummingbirds a choice between a sucrose solution and artificial sweeteners. When offered a choice between non-nutritious sweeteners that produce a response in T1R1-T1R3 and natural sucrose found in nectar, the birds consumed equal quantities of both. However, when offered aspartame which produced no T1R1-T1R3 response, they not only exhibited a strong preference for the natural sugar but they were even seen shaking their heads and spitting out the artificial solutions in disgust! This showed that nutritional information was gained from taste rather than post-ingestive results. Importantly, this gives evidence that the behaviour of the hummingbirds and their taste preference is determined by specific recognition properties of the T1R1-T1R3 receptors.

"Natural selection acts harshly on sensory genes."

If birds and other animals lost the T1R2 gene because they no longer had need for it, that's quite easy to comprehend. But how does a hummingbird go about regaining this ability, all be it in a modified way? "This is a great question, and it's really hard to know for sure!" Maude says. Closely related to swifts, the common ancestor of the two previously foraged on insects. Maude suggests the transition to nectarivory may have occurred coincidentally via insect foraging. "if these swift-like birds started gleaning insects that were feeding on flowers, maybe once they were more closely associated with flowers there was a slight change in the receptor that conferred a slight ability to sense the carbohydrates in the nectar itself." This heightened nutritional intake could have translated to an increased fitness potential and hence evolved via natural selection.

In a continuously changing and variable environment it is the sensory system that perceives these changes and directs a response within animals. The ability to attune and react successfully determines one's likelihood for survival. Natural selection therefore acts harshly on these sensory genes - driving their evolution to maximise survival. The modification of the T1R1-T1R3 receptor has been a huge advantage to the hummingbirds, allowing them to create a whole new niche in which they can gain high-energy resources whilst facing little competition.

However, hummingbirds aren't the only birds to feed on nectar – with orioles, honeyeaters, lorikeets and sunbirds getting in on the action too. So did the mutation and evolution of T1R1-T1R3 to respond to carbohydrates occur multiple times? "Many of these other lineages of nectar-feeding birds are somewhat related, and my suspicion is that the ability to taste sweet evolved a few more times in birds, and maybe then was retained so that many species share the same receptor. I doubt that each frugivorous or nectarivorous species is an independent evolution. But again, we don't have data yet, it's just a hunch." Well, we'll see, Maude's hunches have been pretty lucky so far.

Miranda Walter is a Masters by research student at the University of Exeter's Cornwall Campus. She studies oxidative stress in blue tits.

Baldwin, M.W, Toda, Y., Nakagita, T., et al. Evolution of sweet taste perception in hummingbirds by transformation of the ancestral umami receptor. *Science*. Vol. 345 no. 6199 pp. 929-933. DOI: 10.1126

SPECIES spotlight

photo story

Without knowing better, you might assume that these iridescent colours belonged on the feather of a handsome bird. You'd be wrong. In fact, this elaborate rainbow is found on the abdomen of a species of peacock spider - *Maratus clupeatus*. Dr Jurgen Otto has been studying various species of peacock spider for years, and has become a dab hand at photographing them. He tells us more about the elaborate courtship techniques that the different species share.

"*Maratus clupeatus* is perhaps interesting as it occurs in a relatively small area north of Perth, which is subject to a lot of development. This picture shows nicely the details of the scales or setae. The red ones are rod-shaped and are pigmented , while the blue iridescent ones look more like fish scales and their colour is structural in nature."

"The next image is of the species *Maratus volans*. It is the spider that was thought to be able to fly, hence the name "volans". The person who first collected a few individuals in Sydney, a Mr. Bradley gave them to the spider expert Oktavius Pickard-Cambridge in England and told him that he saw the spider use its flaps to extend its jumps. Pickard-Cambridge believed it and called it the flying spider Maratus volans. When I first saw one I also believed it, their jumps are very powerful. This is the first peacock spider I found, in 2005, and which has probably become the best known of all."

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"I found this in the southwest of Western Australia. It is an undescribed, unnamed species. The image is of a very young juvenile which I raised from the egg and you can see its development so far in my other photo series. I know what the adult will look like but haven't revealed it yet to the public"

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And you think your dance moves are good.

"This last image is of the species *Maratus speciosus*, one that occurs near beaches around Perth in Western Australia. It is one of the most charismatic species"

It turned out of course that the brightly colour abdominal flaps of the peacock spiders were not used to aid jumping after all. Rather it was an elaborate means to advertise quality to females - much like a peacock's magnificent tail. When in the vicinity of a female, a male peacock spider will raise his abdominal flaps and present himself to the female.

"Only then does the true beauty of these spiders become apparent, as patterns resembling faces complete with eyes and lips, bright circles, or a caricature of an entire spider are revealed."

But a beautiful abdominal flap isn't enough, and peacock spiders will pair the presentation of their abdomen with a 'dance' - jumping from side to side and waving their legs in the air.

"It is hard to say whether this show is more impressive to the female peacock spider or the human observer. But seeing one of these tiny males performing its energetic and colourful act seems to defy human logic and experience, as spiders are not an animal we associate with beauty and complex behaviour."

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EXPEDITION: Canadian Arctic

Searching for the light bellied brent.

Words by Professor Stuart Bearhop and Dr Thomas Bodey. Pictures by Professor Stuart Bearhop.

Passing over the twinkling ice caps and snow filled valleys we spot our destination through the helicopter windows – a small, humpbacked, stony island cemented into a solid white sea, too small to merit a name in this vast Arctic wilderness. Everywhere we look the scenery is breathtaking, but seems devoid of life; some rocky patches where the thaw has begun, but inlets and bays remain locked in frozen silence. It is therefore a surprise when a cry of 'brent geese!' comes through the headphones; panicked adults spotted as they take to the wing a few hundred feet below us. This is what we had travelled thousands of miles to find - the birds we had followed on their epic journey from Ireland, via Iceland, and finally to their unlikely breeding grounds in the High Canadian Arctic.

Trying to find a light-bellied brent goose (Branta bernicla hrota) nest in the eastern Queen Elizabeth Islands of the Canadian Arctic is exactly like looking for the proverbial needle in a haystack. We are searching for a duck-sized brown, black and grey bird amidst hundreds of square kilometres of brown, black and grey tundra and braided riverbeds. After a fruitless week, we had begun to fear the worst; perhaps the late snow cover had deterred the birds from breeding, and our hopes of discovering more about their largely unknown breeding biology would come to nothing. This field trip is the culmination of two and a half years of planning - poring over maps, applying for permits, deciding how many biscuits one needs for two months in the field, and getting together a team of researchers from all along the birds' flyway.

So it is with anxious excitement that we wave goodbye to the helicopter pilot and begin to trudge across the windswept, partly snow covered gravel mosaic we have landed on. The four of us spread out into a line to cover a broad transect as we walk along the length of this island. We see the ganders readily enough, but are unable to locate their females on this line. It also turns out that scale is hard to assess in this open landscape as we reach the far end of this 'small' island two hours later! We turn round, moving to cover the other half of the island on our way back and, within a short time, we are finally rewarded. The female sits tight, her graceful neck outstretched parallel to the ground – she will not leave her nest until you almost tread on her, instead hoping your eyesight is not good enough to spot her. One of the best chances to find them is on these small islands where you at least know the total area you can possibly search.

She eventually opts for self-preservation and moves a short distance away. We notice with delight that she is a bird previously ringed in Ireland, UN white-red. She has revealed a clutch of five large, cream coloured eggs, nestled in dark grey down plucked from her own breast to act as the most fantastic insulation. She remains nearby, spreading her wings to make herself more intimidating, hissing and honking in alarm. After all, these eggs represent a phenomenal investment. As we weigh and measure the eggs, we calculate that this clutch adds up to almost one quarter of her pre-migratory body mass. The lack of vegetation up here means that she is a capital breeder, having to carry all the resources required to produce this clutch with

"How many nests fall prey to Arctic foxes, wolves or even polar bears?"

her during migration. This is on top of the resources required to power her flight here from Iceland – a distance of around 3000 kilometres across the Greenland icecap to a nest site only 500 miles from the north pole. The effort this entails year on year is simply incredible.

Much of what we know about these amazing athletes of the sky has been carried out on their wintering grounds in Ireland where the brent spend almost six months of the year. This has revealed many intriguing aspects of the ecology of these birds. For example, if you watch feeding geese you can readily assess how much fat they are carrying, as it is stored on their belly and abdomen - just as in humans. This can be scored on a 1-7 scale and, although it sounds simplistic, the amount of fat on a bird in late winter in Ireland has been a good predictor of whether that individual will return with juveniles the following autumn - some eight months later. Successful breeders migrate with their young and stay in these family groups throughout the winter, so juveniles learn the route and where the best feeding spots are from their parents in their first year of life. However, for the last three years, almost no young birds have arrived back in Ireland in the autumn. One of the key goals of this trip to the Canadian Arctic is to explore the black box that is their breeding biology. What happens up here in this starkly beautiful wilderness? What might be the cause of the recent breeding failures? The short breeding season means that birds have little scope for dealing with any delays, so could a changing climate be playing a role? How many nests fall prey to Arctic foxes, wolves or even polar bears? What do the adults, and more importantly the chicks, eat in this stone desert? So many of these simple and not so simple questions are currently met with the answer "we can speculate, but we just don't know".

We do know that brent are the most marine of geese, spending their time in Ireland and Iceland, grazing on intertidal seagrasses and on fields close to the sea. We also know by looking at the molecular signatures in their blood and comparing it to the signatures of the types of food they eat, a technique called stable isotope analysis, that marine derived nutrients are hugely important in allowing the birds to regain body condition after these long flights, and for preparing them for the ones to come. However, as the birds deplete these marine resources by consuming them juveniles, which are less experienced foragers, are unable to find enough food and so switch to fields where the food is less nutritious but more abundant. As the family remain together, their parents are also dragged away from their preferred food sources, and the results carry-over into subsequent parts of their annual cycle. Birds feeding on fields end up taking longer to gain weight, so they leave Ireland and arrive in Iceland later than birds that fed more on the estuaries throughout the winter.

"How are their bodies able to cope with such changes that would kill a human being?"

In Iceland they then find it harder to get access to the best food sources as the early arrivers have already staked a claim to them, and so, except in very good years, rearing young in one year makes it extremely hard to breed successfully the following year as well.

Incredibly, these parents that are playing catch up don't just stay behind in Ireland or Iceland, they still make the whole migration to the Canadian Arctic. Another question we are keen on answering is, are birds always physiologically geared up for breeding, or are they able to make the decision in Iceland or Ireland that this is a year for conserving resources and looking after number one? This year we have made a start on answering this question, examining females in Iceland to see if they are all growing in the down that will form their nest, and taking blood samples from all individuals to look at hormone levels which will give us an idea of the stress the birds are under and how their immune systems are functioning. These results will also allow us to address another fascinating question. How are their bodies able to cope with such changes that would kill a human being? Their bodyweight can increase by over a third in 3-4 weeks in Iceland, followed by huge amounts of energy expenditure in less than a fortnight of migration, then essentially starvation rations on these barren islands for another month.

Our day in the Arctic continues, in fact it never really ends as the sun will not set here for another two months. We visit further specks of land, possibly the first people to set foot on them, and find 23 nests - more than have ever been found before. For the next two months we will monitor what happens to these birds and their nests, and if we are able to ring them, will they be seen by us, or one of the many volunteers who contribute sightings to the Irish Brent Goose Research group, in the relatively balmy Irish winter? And what allows the geese to adapt to this huge range of habitat types? Here we are privileged to see them breeding in the vast, empty spaces of the Arctic, and yet we will be able to see some of these self same birds cheek by jowl with joggers, golfers and traffic in central Dublin! As the helicopter lifts off to return us to our remote camp, we hope we will be lucky enough to see UN white-red, and perhaps even one of her chicks, back in Ireland later this year.

WORK HARD TAKE CHARGE STRESS OUT

Do the healthiest among us work the hardest? Can hard work damage your health? Evidence from white-browed sparrow weavers suggests high work-rates can indeed take their toll on bird health. .

Words and pictures by lead author Dr Dominic Cram

Balanced precariously atop a ladder, I reached into the darkness, slowly lining up my trusty capture-nets with the grass roosting chamber. I waited for the breeze to die down, then a final moment's concentration - and a white-browed sparrow weaver leaped into my capture net. I sprinted back to the car, dodging a bemused aardvark along the way.

White-browed sparrow weavers *Plocepasser mahali* of the South African Kalahari Desert are not the most attractive birds, but what they lack in flamboyance, they make up for with their fascinating social lives. Our team, led by Dr Andrew Young at the University of Exeter, have been studying sparrow weaver societies since 2007. The birds live in cooperatively breeding groups, where workloads are shared between group members. While this may sound harmonious, the workloads are in fact distributed unequally. The dominant pair work hardest: dominant males invest most in territory defence, mate attraction, and singing a complex dawn song, while the dominant females lay and incubate eggs, and provide most food for the chicks. Subordinate birds work less hard – and don't breed at all – instead providing food for the dominants' chicks. Sparrow weaver societies can therefore give us an interesting opportunity to study how work-rates are linked to health. Are the dominants hard-working because they are healthier, stronger birds? What are the health consequences of hard work – do the dominants end up worn out and suffering from poor health? These are the questions I wanted to answer, using this unassuming little brown bird.

" I had some healthy weavers, and some who were really struggling."

Back in the Kalahari, and my sprint had dwindled to a feeble jog. Catching the weavers as they roost at night is much easier than during the day, but the heat of the Kalahari summer was stifling even after sunset. I sweatily staggered to our car which was, in truth, more of a 4 × 4 mobile laboratory in the desert. The tools of the field ornithologist's trade were laid out before me. I weighed and measured the feisty weaver, and took a small blood sample. The field centrifuge whirred into action, the blood was divided into plasma and red blood cells, and the samples were processed, ready for laboratory analysis.

My research focuses on the links between work-rates and a particular component of the weavers' health – their oxidative status. Harmful reactive oxygen species (ROS) are generated as a by-product of normal biological processes: they are produced in me as I type this, in you as you read it, and in the weavers as they go about their daily lives. Under normal conditions the harmful effects of ROS are minimized by the body's antioxidant defences. However, hard work – such

as the birds' frenzied feeding of ever-hungry chicks, or similar stressful and intense physical exertion in humans – risks over-powering the antioxidant protection, allowing ROS to cause cellular damage and ultimately, oxidative stress. Oxidative stress has been implicated in a number of diseases, reduced reproductive success and ageing. So, do dominant weavers work hardest because they have exceptional antioxidant protection? And does their hard work take its toll, increasing cellular damage and promoting oxidative stress?

Sparrow weaver HQ was oddly enough, an old converted police station in the Kalahari, where I sat in my re-purposed prison cell, planning my study. To investigate whether dominants had superior oxidative statuses (lower oxidative damage and/or higher antioxidant protection), which allowed them to maintain their higher work-rates, I needed to sample as many dominants and subordinates as I could before the breeding season began. I also wanted to investigate whether all their hard work left the dominants suffering from oxidative stress. To do this, I had to sample the birds after the breeding season was over. I scanned down the list of all the sparrow weavers in our population, highlighting my target birds. I needed a balanced dataset: plenty of males, females, dominants and subordinates. I was also worried about confounding between-individual differences: if I captured one set of birds for the before samples, and a different set for the after samples, I wouldn't know whether the results reflect interesting effects of hard

Blood is taken from under the wing of the sparrow weaver using a glass capillary tube. This is then analysed back in the laboratory.

work, or uninteresting differences between my random sets of birds. After long deliberations in my dusty prison cell, I decided to capture the same birds before and after the breeding season. Before long I was bouncing along the sandy road in my 4 × 4, with a long list of target birds, ready for another long night of captures.

Three months later, in a windowless constant-temperature laboratory at the University of Exeter's Cornwall Campus, the weaver's song and the stunning African wildlife were a distant memory - I was just a little less likely to meet a rare desert black rhino on my commute to work. Nonetheless, this was where my samples really began to answer the all-important questions.

I lined up 40 blood samples in tiny glass vials. The auto-sampler sprang into action, and a robotic arm lowered a needle into the first vial. The needle transferred the blood into a fluorescence detection column, and after a few moments, a curved graph emerged on the screen. It told me that this particular bird had harmfully high levels of oxidative damage to his lipids – which are crucial components of the cell membrane. His antioxidants clearly cannot cope with the ROS threat, and he was probably suffering similar oxidative damage to his proteins and DNA. Eventually, this can lead to tissue damage and cancer. This was not a healthy bird.

I left the auto-sampler to assay each glass vial in turn, and I began measuring antioxidant protection. To do this, I added a coloured synthetic ROS to the blood samples. As the antioxidants in the blood neutralized the coloured ROS threat, the pigment was lost. Blood samples with the strongest antioxidant defences remained uncoloured, while those from weaker birds turned a sickly green. I lined up 96 blood samples in the spectrophotometer, and hit 'Scan.' In seconds, it measured them all, firing a laser through each sample, and measuring the absorbance (a proxy for the colour) of each. I could immediately see I had some healthy weavers, and some who were really struggling. After double-checking the data, it was finally time to run statistical models, to investigate differences in oxidative status between subordinates and dominants.

The results suggest that the hard work of dominant males and female weavers is not due to intrinsic high quality and strong antioxidant defences, because they do not differ in oxidative status from subordinates before the hard work begins. We can also rule out the hypothesis that dominants strategically up-regulate their antioxidants in preparation for their intense breeding season – there is no evidence of this occurring.

All too often in research, 'negative results' like this are deemed uninteresting, given little attention and sometimes never published at all. Negative or not, I'm fascinated by this finding: even though dominants invest massively more in key activities including reproduction and territorial defence, they are

indistinguishable from subordinates in their oxidative status before the breeding season. How can this be the case? How can they work so much harder without having stronger antioxidant defences?

The next result may give us a clue. Data from after the breeding season revealed that dominant females suffered a sharp decline in their antioxidant defences over the course of the season, while subordinates did not. Dominant and subordinate males showed no differences – it's the dominant females that lay and incubate all eggs, and work hardest to provide food for the chicks. Since they don't begin the breeding season with stronger antioxidant protection, this high work-rate appears to take its toll on their health, consuming large portions of their antioxidant reserves and leaving them exposed to oxidative stress-related diseases and ageing.

As I wrote up my findings I reflected on the highs and lows of the 18 months it took to plan the study, collect enough blood samples, carry out lab-work, and interpret the results. The long catching sessions, the frustration of an escaping bird, the 18-hour days in the lab - research is full of these challenges, but it's also an incredibly rewarding process. My results shed light on a poorly understood link between sociality, work-rates, and health. At least in sparrow weaver societies unequal divisions of labour can leave the hardest-working individuals exposed to oxidative stress, which could have important implications for health and ageing. My hope is that my future work, and that of other researchers, can build on these findings and further clarify the health consequences of sociality and work-rates.

Cram, D L, Blount, J D, & Young, A J. (2014). Oxidative status and social dominance in a wild cooperative breeder. *Functional Ecology*: DOI: 10.1111/1365-2435.12317

I FEEL YOUR FATIG

A new study in captive wolves shows that they experience the yawn contagion - but does this put an end to the debate on whether animals can be empathetic?

Words by Dr Claire Asher

Yawns are contagious. We've all experienced it. That one person yawning in the morning meeting that sets everybody else off. Contagious yawning is thought to be more than just an amusing artefact of human behaviour though; rather it may be an important tool for coordinating the behaviour and physiology of a group. Yawning has been found to influence activity levels in humans and chimpanzees, with yawning triggering an increase in activity (counter intuitive, I know!).

Contagious yawning is amazingly flexible – humans can catch a yawn by seeing it, hearing it, even just reading about yawning can be enough to trigger one (you're probably yawning right now, aren't you?). Although it is not considered an emotional reaction, when one person 'catches' a yawn from another, neural

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representations of the behaviour and physiology of the yawner are triggered and replicated in the brain of the observer. It has therefore been linked to our capacity for empathy.

Functional magnetic resonance imaging (fMRI) has revealed specific areas in the brain that are activated as one individual 'catches' a yawn; blood flow increases to the superior temporal sulcus, an area thought to be involved in interpreting social cues. Humans aren't the only species to be able to catch a yawn from another. There is evidence for contagious yawning in various non-human primates including gelada baboons *(Theropithecus gelada)*, chimpanzees *(Pan troglodytes)* and bonobos *(Pan paniscus)*. As in humans, the findings from these yawn studies supports the idea that the yawn contagion is an intermediate form of empathy, being more frequent between those with social bonds. Close relationships are important when it comes to feeling empathetic towards another individual.

Research into contagious yawning outside of the primates has only begun recently. In 2008 a study found inter-species contagious yawning between humans and domestic dogs. Further research indicated that, like humans, dogs can catch a yawn just from hearing it and that social bonds were again important in triggering yawns. The existence of empathy in dogs would suggest a much earlier evolutionary appearance, with the trait potentially being shared by all mammals. However, no evidence exists for contagious yawning from dog to dog, and from studies in domestic dogs alone, we can't be sure that contagious yawning isn't merely an artefact from the process of domestication.

A new study recently published in PLOS ONE set about to clarify whether the yawn contagion had indeed evolved naturally within canines by studying a population of captive grey wolves *(Canis lupus lupus)*. Dr Romero and colleagues from the University of Tokyo performed over 250 hours of observations on a pack of

12 wolves at Tama Zoological Park in Tokyo. Upon the yawn of one individual, the surrounding pack members were watched for 3 minutes to determine if any further yawns were elicited from them. When comparing this with a control period they found that yawns were far more common in wolves that had recently observed another pack member yawn. Wolves would also yawn more often when they were looking in the original yawner's direction.

This study is the first to demonstrate contagious yawning within an undomesticated species of carnivore. Being relatively far on the evolutionary tree from primates, "these results suggest that contagious yawning is a common ancestral trait shared by other mammals and that such ability reveals an emotional connection between individuals" explains Dr Romero.

Just like humans and other primates, wolves were also more likely to catch a yawn from individuals with whom they shared a closer social bond. According to Professor Frans de Waal, animal behaviour expert at Emory University, Atlanta, the study "confirms the idea that basic empathy is a mammalian characteristic, found in animals from mice to elephants".

The authors advise caution due to their small sample size, but they found that female wolves would also yawn a lot faster the more closely affiliated they were with the yawner. However, this was not true of male wolves, they were unaffected by the closeness of their relationships. The authors suggest this is indicative of a higher ability in females to react to the emotional states of others. A similar pattern has been found in other animals, leading academics to conclude that females are generally more responsive to social cues than males. de Waal explains that the greater responsiveness of females to contagious yawning is consistent with evolutionary thinking that empathy originated with maternal care. "This is where the initial advantages were" he added, "with females paying attention to the emotional states - hunger, distress - of their young. This is probably also why in our own species women have universally more empathy than men." Since these evolutionary origins, it is thought that empathy has been beneficial to social animals, enabling them to promote social connectedness – imitation is the highest form of flattery after all.

What significance does this have towards our understanding of empathy in animals? "Empathy is multi layered. Yawn contagion probably resides on the simple end of the spectrum" says de Waal. Scientists first started looking for signs of empathy outside of humans in the 1970s, and naturally they turned to our closest relatives, the great apes. During experiments, chimpanzees have demonstrated an understanding of the viewpoint, knowledge and goals of others, and in many cases anticipate their behaviour in similar ways to human children. There is evidence for consolatory behaviour in Chimpanzees – after conflict or aggression, a third party will often give the

loser a hug, alleviating stress after the event. A bystander is more likely to console in the absence of reconciliation between the conflicting partners. The two warring parties have also been observed to reconcile post-conflict in the form of kisses, hugs, handshakes and popping fingers in each other's mouths!

The existence of human characteristics in non-human animals is always debated. And this post-conflict consolatory behaviour has been argued to have evolved due to the necessity of restoring social cohesion, rather than a result of empathetic emotions. However, Asian elephants *(Elephas maximus)* show signs of consolation in response to a non-conflict distressing event; elephants that observe distress in another elephant will tend to comfort them with physical contact and chirping vocalisations. Consoling elephants also seem to mirror the emotional state of the distressed individual, which strongly suggests this is a sign of empathy.

Whether animals exhibit empathy is important for the way we understand the development of non-human intelligence. We often take for granted our ability to assess the intentions, thoughts and knowledge of others around us, but it is an important tool underpinning all of our social interactions. The ability to understand and anticipate the behaviours of others and know that they might be different from your own is known as possessing a 'Theory of Mind'. Although this too was long considered a uniquely human characteristic, research is now revealing these abilities in a wide range of animals including primates, dogs, birds and ungulates.

Corvids such as crows, rooks and scrub jays are intelligent and very sociable, often living in flocks and forming close social bonds. They show strong evidence of social cognition including an awareness of the viewpoints and knowledge of others. Western scrub jays (Aphelocoma californica) bury food to eat later, a behaviour known as caching. But, not all scrub jays are honest and some birds will steal cached food. Scrub jays that have previously stolen from others are wise to this game however, and if they are watched when burying food they will sneak back later to move their stash to a more secure location! They understand that by moving their cache the observer will have an incorrect perception of its location.

For us, empathy is one of our most powerful tools in navigating a complex social world; we use it constantly, when interacting with strangers, friends, relatives and prospective mates. This recent work by Dr Romero and colleagues suggests that it evolved much earlier than previously thought – perhaps being ubiquitous among mammals. Expanding this research to other intelligent social mammals will continue to reveal deep insights into our most precious mental abilities - those that allow us to survive the social world around us.

Dr Claire Asher completed her PhD in social insect behaviour at the University of Leeds, and currently works as Knowledge Transfer Officer for the Centre for Biodiversity and Environment Research at University College London.

Romero T., Ito M., Saito A., Hasegawa T. (2014) Social Modulation of Contagious Yawning in Wolves. *PLoS ONE* 9(8): e105963. doi:10.1371/journal.pone.0105963

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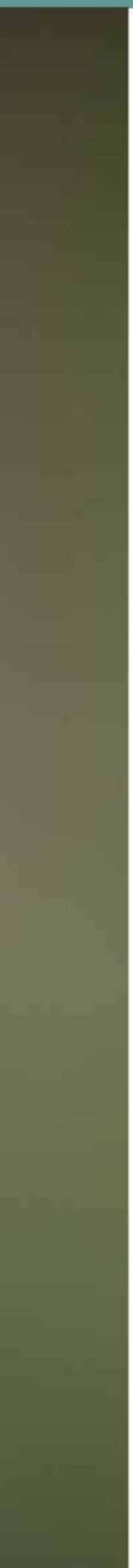
EVOLUTION for CONSERVATION

A recent study translocating brown Anolis lizards highlights how we can utilise evolutionary principles for proactive conservation efforts.

Words by Dr Amanda Bates for The Conversation



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Lizards from the deserts of Australia to the tops of mountains in Costa Rica have given us insights into how animals take advantage of their environment to be less cold-blooded. Lizards seek out sunny patches or the warm underside of rocks where they can soak up the heat to enhance digestion or run faster. When it gets too hot, they can escape the heat by finding shade or retreating to burrows underground.

In particular, tropical species, including lizards, are thought to be especially vulnerable to climate warming because they already live at temperatures that can be dangerous. Without the sweat glands or metabolic control that mammals take for granted, lizards can heat up very quickly if they find themselves caught out in the sun for too long.

Species living in the tropics are also thought to have behavioural adaptations that are finely tuned to stable and predictable weather regimes, such as daily activity rhythms. Such behaviours that may be ill-suited to the increasing variability that is predicted with climate change where flexibility may be an asset.

In a world of greater climatic extremes, lizards may over-expose themselves to dangerous temperatures, or may find themselves with only a few opportunities to feed or find mates if their activity patterns are constrained to a particular window in temperatures. This question of how animals might respond to a warmer and more variable world is the focus of a new study aimed at understanding how evolution might come into play as our climate changes. Are species' current tolerances and behaviours fixed – or can we expect scope for rapid evolutionary change through adaptation? Will some animals be saved by evolution?

Michael Logan from Dartmouth College in the US conducted a clever experiment with his colleagues to test whether tropical lizards have the potential to change their physiology over generations to better adapt to a warmer environment, but also one that is less predictable. The authors moved a population of brown anole lizards *(Anolis sagrei)* from a forested site in the Bahamas to a nearby open peninsula where daily temperatures on the ground were more than

"Even though evolution may rescue some species as the world warms, we don't factor it in to our predictions"

2°C higher than the lizards were used to. They found that in a warmer and more variable climate, those lizards that survived functioned better in the heat, were fast and were also active over a broad range of temperatures.

The authors conclude that a new environment rapidly selected the lizards that were best suited to survival. They expect subsequent generations of peninsular lizards will continue with hard-wired evolutionary changes in their physiology and behaviour – eventually a new form of the species may emerge, tailored to towards the hotter peninsula. Even so, the authors do not distinguish whether the shifts in the characteristics of the peninsular lizards are genetically based, which would be a prerequisite for evolutionary change – the traits need to be heritable and passed on to subsequent generations. Indeed, there isn't much evidence for genetic change in response to climate change.

Yet animals as diverse as pink salmon and soil mites have shown rapid evolutionary changes can occur in just a few generations, as opposed to the typical view that evolution takes hundreds of years to manifest itself. Yet even though evolution may rescue some species as the world warms, we don't factor it in to our predictions of which plants and animals will be the most vulnerable to climate change.

There are some obvious reasons for this. While "rapid" evolution is possible, it still takes a while to unfold

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– longer than the duration of typical research grants and PhD programmes. For some slow-reproducing species, such as those from cold polar environments or large mammals, it may take decades or more to observe. Only the most patient evolutionary biologists would devote their life to investigating how each generation of elephants has further adapted to climate change.

The capacity for evolutionary change is also tricky to predict as so much depends on context. Some populations of a particular species will contain individuals with certain characteristics – the capacity to tolerate extreme heat, say – that will allow those individuals best suited to a new environment to survive and the population to carry on, as seems to be the case in the brown anole lizards experiment. Other populations, without these adaptable individuals, will simply die out.

We presently face the most exceptional extinction rates of modern times. Rapid environmental change is already outpacing the capacity for many species to adapt and survive, but certainly some will beat climate change.

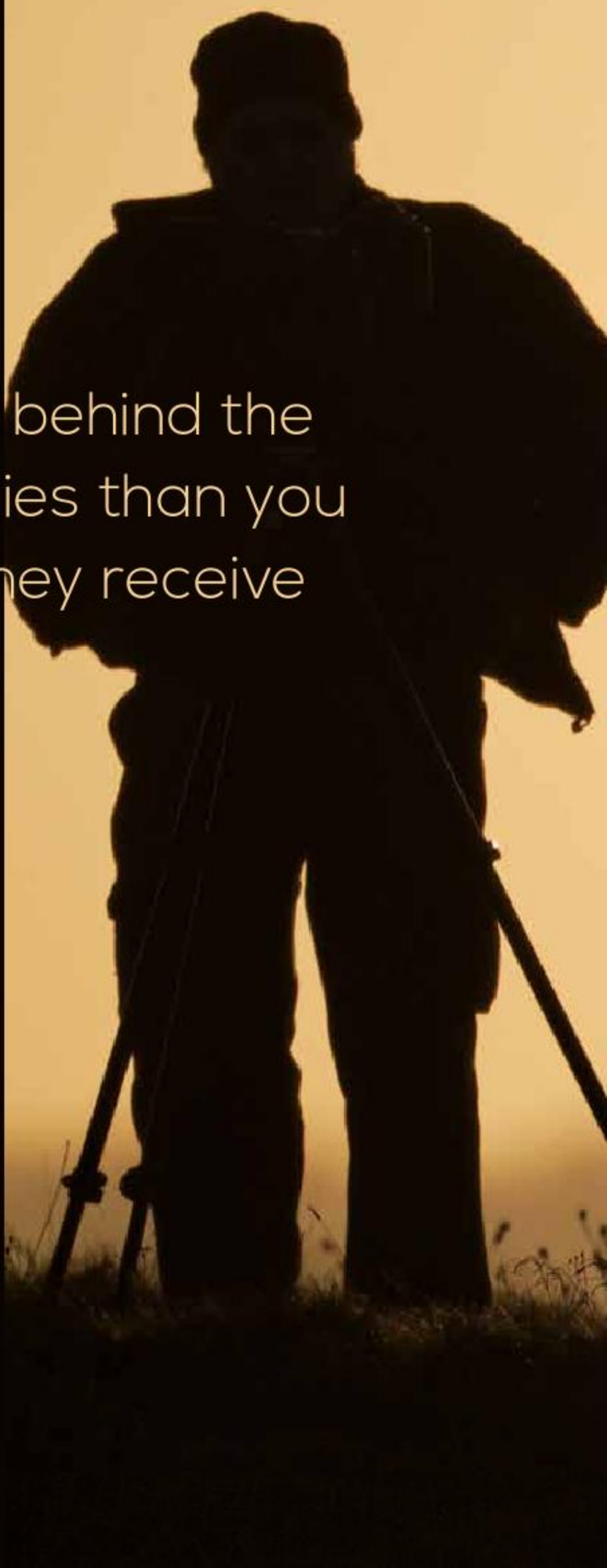
One of the big questions this research poses relates to conservation: which species can we best assist through establishing new populations and supplementing declining populations with measures such as artificial breeding programmes? But this may be too narrow a focus. These fast-adapting lizards show that evolutionary change itself could yet be put to good use in conservation.

While efforts have focused on saving threatened creatures by moving populations to safer places or trying to preserve their habitats, this study shows that moving them to more extreme environments can pre-adapt populations to a warmer world. Crucially, it suggests another tool to help identify those species that will have a chance under climate change and opens the possibility that we could give some species an adaptation head start.

Dr Amanda Bates is a lecturer in macroecology at the University of Southampton. www.theconversation.org

Logan, M.L., Cox, R.M. & Calsbeek, R. (2014). Natural selection on thermal performance in a novel thermal environment. *PNAS* doi: 10.1073/pnas.1404885111

Our silent workforce



Citizen scientists are behind the scenes of more studies than you might think. Should they receive more credit?

"One of the questions that people always ask me is - are citizen science observations any good?", laments Dr Caren Cooper. Thankfully, citizen science champion Cooper now has some hard stats to back her claims that, yes, they are.

She led an investigation, reported recently in PLOS ONE, which found that half of the studies cited in an expert review of climate change's effects on bird migration relied on data collected by non-professionals. Such 'amateurs' included bird watchers and nature enthusiasts, who through their love of wildlife had voluntarily gathered and reported sightings of birds, amassing valuable scientific information that the pros have drawn upon.

Importantly, the bird migration review made no distinction between the strength of research underpinned by citizen science to that wholly-conducted by professional scientists. In fact, it judged many of the studies using volunteer data to provide 'strong evidence' that birds are now migrating earlier in spring in response to our changing climate, for instance.

Those with a keen interest in citizen science may not be too surprised that it is deemed a perfectly serviceable

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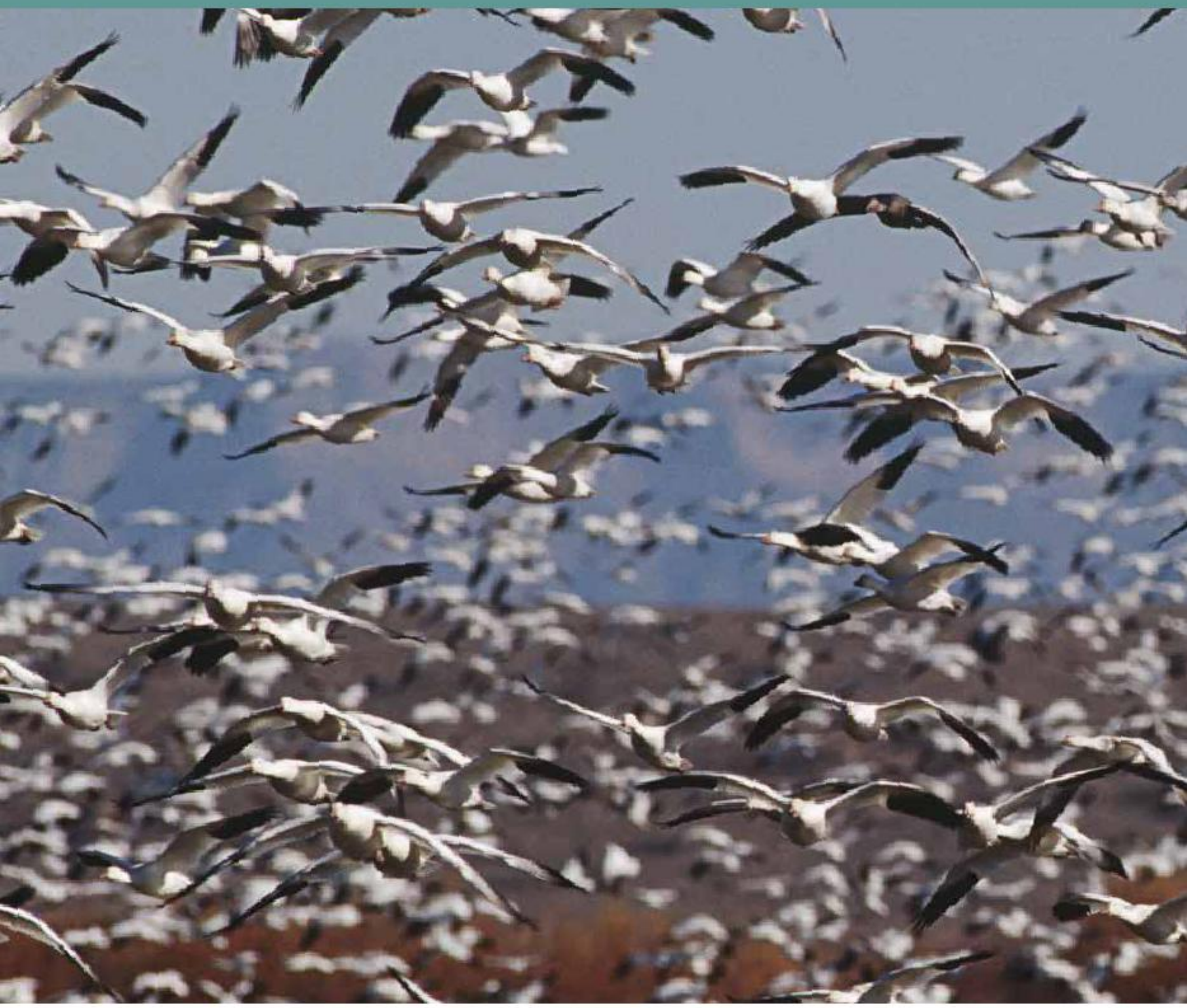

form of research. Indeed, Cooper et al's paper points to a study which found that community-led monitoring of tropical species has yielded much the same results as monitoring carried out by trained scientists. Furthermore, birding is a hobby blessed with such public enthusiasm that the so-called amateurs often know just as much – if not more – than their academic counterparts about our feathered friends.

However, what did surprise Cooper, a research associate with the Cornell Lab of Ornithology in the US, was that neither the review nor any of the papers it cited made any reference to 'citizen science'. The ordinary folk upon whom bird research so heavily-depends are thus an 'invisible' workforce, her paper declares.

"I expected the number of papers in our sample which mention 'citizen science' to be fairly low", Cooper explains. "But I was surprised that zero papers used the term". While a number of the 84 citizen science studies in the migration review did acknowledge the 'volunteers' that played their part in the research, 37 of them made rather nebulous mentions, if at all, of any non-professional involvement. Cooper and her colleagues were only able to reveal the citizen science element with some diligent detective work and through their own knowledge of bird programmes and organisations referred to in the papers.

She therefore describes her *PLOS ONE* paper as a thank you to the many people who are citizen scientists. "These people are part of the process of creating new knowledge - and whether it's counting birds or butterflies, gazelles or galaxies, they should know that their observations really make a difference in professional science."

The team's results "point to the potential of the millions of global participants whose 'invisible' efforts may be contributing to new discoveries", their paper concludes. And they're not just talking about ornithology either. They suspect that citizen scientists often go uncredited in many fields of research, including land use change, invasive species and environmental pollution, to name but a few.

They urge academics who draw on the work of non-professionals to use the keyword 'citizen science' in their papers. This would allow people interested in the subject to easily track and assess

its use in research databases, they propose. Critically, they also call for everyone to consistently use the term 'citizen science' to increase its visibility.

The benefits of greater recognition for citizen science? It could help boost the number of participants, they suggest, as well as the social impacts of science. Many of these impacts arise through participants being more than just a diffuse set of eyes and ears for the scientific community, but as engaged with the entire research project and process, Cooper believes. This engagement can be realised if project leaders understand the importance of communicating their findings back to volunteers.

A more visible citizen science could even help increase public acceptance of controversial topics, such as climate change, she suggests, by strengthening public understanding of, and trust in, the work behind it.

"Science is often viewed as occurring in a black box, off in the ivory towers, which can be a little disconcerting when pretty bad news is delivered", Cooper says. "Citizen science helps open that black box a little because then scientists and the public are working together. It can help break myths about science. There may even be "onlooker" effects where people who don't contribute data themselves, but follow and know about the project, also learn."

Her *PLOS ONE* paper came as a bit of surprise to the lead author of the bird migration review that it dissected. "I felt it was a bit strange that they did not consult us beforehand", comments Nils Christian Stenseth, Professor of Ecology and Evolution at the University of Oslo.

None-the-less, he says he wholeheartedly supports the citizen science cause, and does not seem particularly surprised by Cooper's findings either: "I certainly was aware that so much of the data in the papers we cited had been gathered by citizen scientists. It has no effect on how I perceive the quality of those papers." He continues: "I fully agree [with Cooper et al] that citizen science should be made more visible. Indeed, I feel that ecologists have ignored such data far too much. This is very unfortunate as such data might hold valuable information."

So why have citizen science efforts gone underreported? Cooper

doesn't believe that academics are downplaying its role: "Most of the time I suspect that the authors of the paper don't think to acknowledge citizen science. They describe the methods and will usually mention the source of the data, and often thank volunteers in the acknowledgements. But they don't have reason to label the study as citizen science.

"It isn't as though their findings are different or better or worse because of the contribution of citizen scientists. But I hope our paper has shown there are reasons [to report citizen science-gathered data more transparently], so that we can track the contributions of the public and so that we can better acknowledge their efforts."

A positive shift in academics' attitudes towards citizen science in recent years has been noted by the University of Exeter's Dr Martin Stevens. Although he can't be sure of what exactly is behind this change, as with many things in life, it may be to do with money – specifically, the influence of the organisations that fund academic research.

"Funding councils in the UK are encouraging researchers to think more and more about the social impact of the work they finance, and to engage more with the public. This has made a bit of a difference to researchers' attitudes towards things like citizen science", he suggests. "The rise of social media, such as Facebook and Twitter, has had an impact too. We've used these channels to recruit participants and, thanks to social media, it now comes much more naturally to share what we do with the wider public".

Stevens leads Project Nightjar, which investigates camouflage –an important tool in birds' survival strategy. Perhaps one of the project's more 'eye-catching' elements is a series of online computer games which test the public's bird and egg-spotting skills – when those birds and eggs are cleverly hidden amongst the undergrowth.

Although the games started life as a promotional offshoot of the wider project, their potential in gathering huge amounts of data from an enthusiastic public was soon realised by the project team. The eagle-eyed efforts of the estimated 20,000+ players so far have helped produce real results on the effectiveness of different camouflage strategies found in nature that Stevens and his colleagues are currently writing up into scientific papers.

He certainly has no issues about openly advertising the public contributions to the project: "In our papers, we absolutely plan to acknowledge the citizen scientists who played our games. It's all very much in the spirit of the project's openness. The papers

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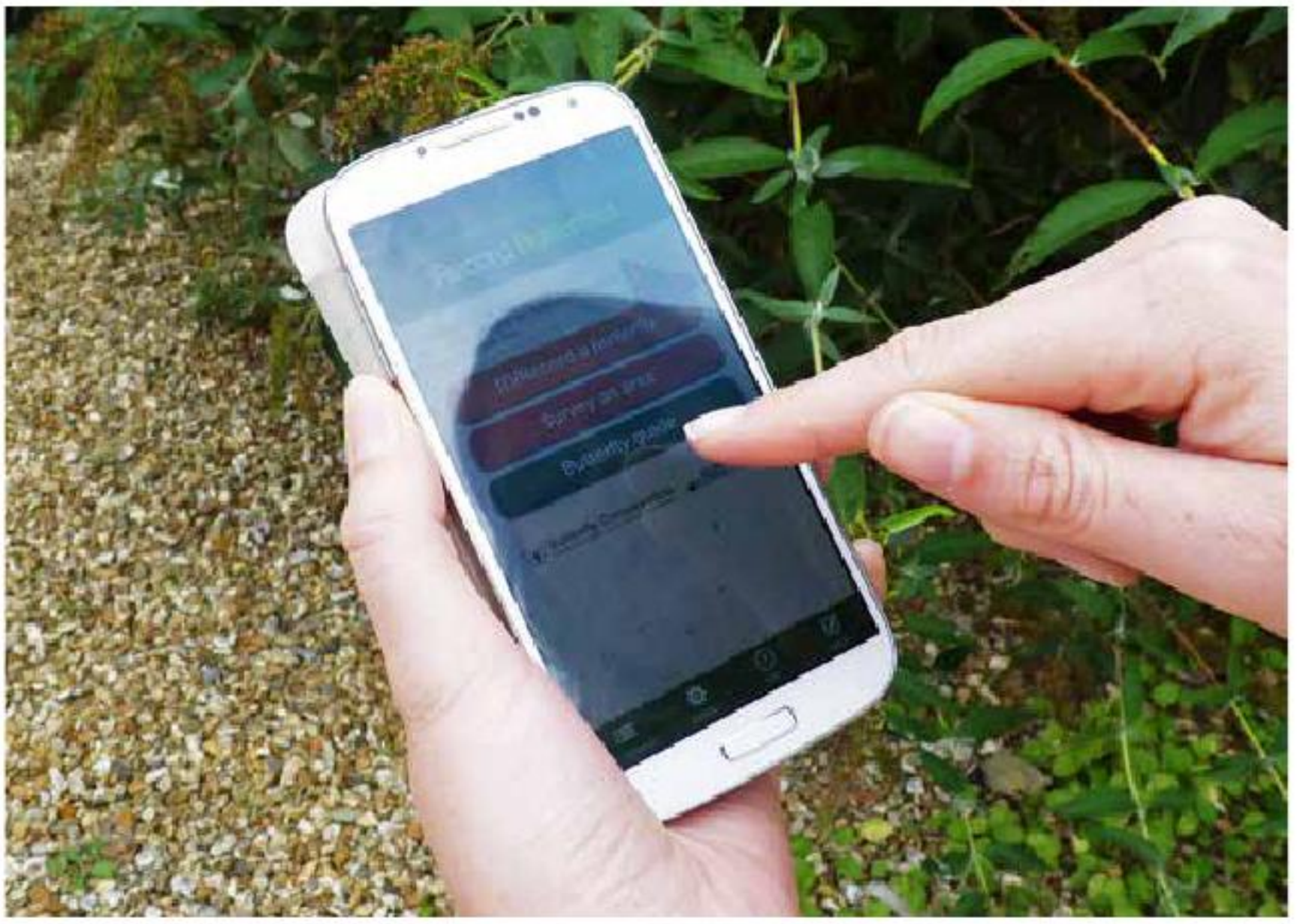


themselves will be open access and even the code for the games is open source and available from our website".

He's perhaps less convinced by the argument that researchers should consistently use the term 'citizen science', as suggested by Cooper et al: "I'm not really surprised that they didn't find any papers that used the term 'citizen science', because really it's just a question of what you choose to call it. Scientists have been working with volunteers for years; it just didn't really have a name until recently.

"It's not important what you call it. What is important is that the people taking part know that they are contributing to real science."

Project Nightjar's games form part of a new wave of citizen science that uses internet technologies; what has been described as 'citizen cyberscience'. Other notable examples include the work of Cooper herself and her colleagues at the Cornell Lab of Ornithology, an influential research group in the world of environmental citizen science. The Lab's Yardmap project, which claims to be the first citizen scientist social network, allows users to map and discuss online the habitats of wildlife in their gardens.

One example in the UK includes the Big Butterfly Count. Once a year, over 40,000 members of the UK public spend 15 minutes logging butterfly sightings, with a little help from an ID chart, via a smartphone app. The NGO Butterfly Conservation use the data to help assess its work and to direct its future conservation efforts. Meanwhile, the ash dieback game Fraxinus, playable on Facebook, allows anyone to indulge their inner geneticist with a little gamified DNA sequencing. And so thanks to apps, online games and social networks, you no longer need to be a seasoned birdwatcher or science expert to play your part in research as a non-professional. You don't even need to leave the comfort of your sofa.

The spotlight on citizen science continually shines brighter, not only with its increased accessibility and media attention bestowed upon it, but also through its professionalisation. The latter is marked by several recently-formed societies, including the Citizen Science Association in the US, the European Citizen Science Association and the Citizen Science Network Australia. As co-chair of the Citizen Science Association's publishing committee, Cooper is also involved in setting up a new academic journal devoted to citizen science.

Whether citizen science is openly credited by academics or not, Cooper's research does serve to expose the major part that non-professionals play, certainly in bird research, while also vindicating proponents of doubts around the quality of citizen science; "all data collection has quality issues that need to be addressed, whether citizen science or experiments in a lab", she argues. And as its prominence grows, fingers crossed, there is little risk of citizen science languishing behind the scenes for much longer.

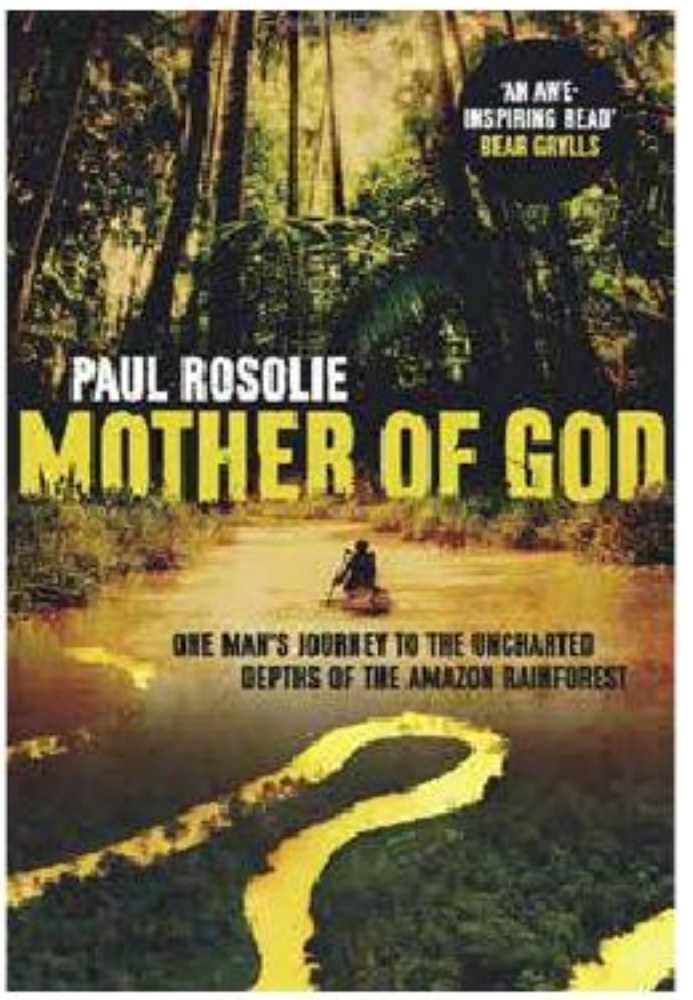
Michelle Kilfoyle is a Science Writer in the University of the West of England's Science Communication Unit.

Cooper, C.B., Shirk, J., Zuckerberg, B. The Invisible Prevalence of Citizen Science in Global Research: Migratory Birds and Climate Change. *PLOS ONE*. DOI: 10.1371/journal.pone.0106508

RECOMMENDED READS

INTO THE UNKNOWN

I opened up 'Mother of God' on the wrong page. Staring back at me was Paul Rosolie's rather infected and miserable looking face. "I was sure I was dying", he had written underneath. I knew from this point that it was going to be a good read, even if I did have to take a good look at a healthier photograph of Paul in order to stop my mind conjuring up that image whenever I read. Paul takes us into the heart of the Madre de Dios in Northern Peru, and even though we may have never been there you feel captivated - as if you're exploring it with him. Although, as a reader we do get to spare ourselves the blisters, bites and other injuries that Paul does not restrain from telling us about. It's a love story - with nature, with wilderness and with a woman. And like many love stories, this one is intermingled with sadness and struggles, but leaves us hopeful and energised that with passions strong enough, we can turn the tables on our collective fortunes.



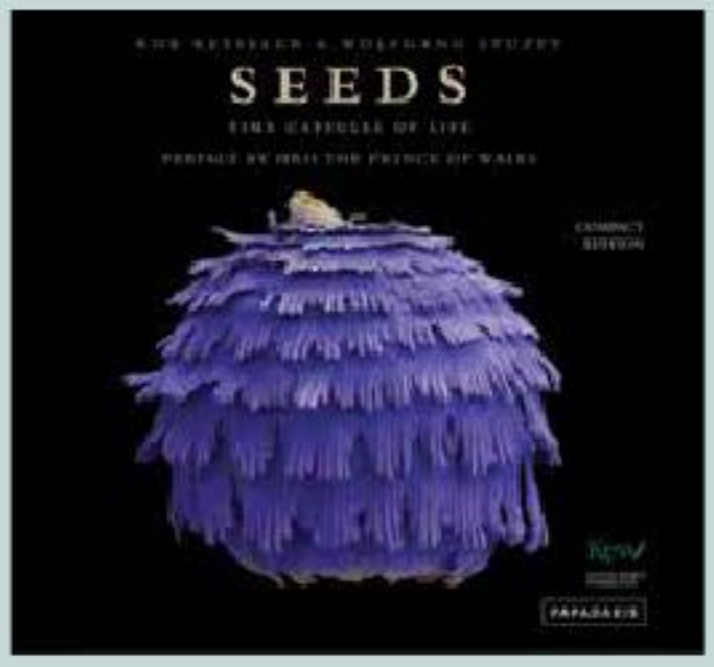
Paul Rosolie ventured into the wilderness when he was 18, and it accepted him as one of its own. Now he is an experienced naturalist and explorer who has specialised in the Amazon rainforest for more than a decade. He runs Tamandua Expeditions - which aims to aid rainforest conservation through responsible adventure tourism.

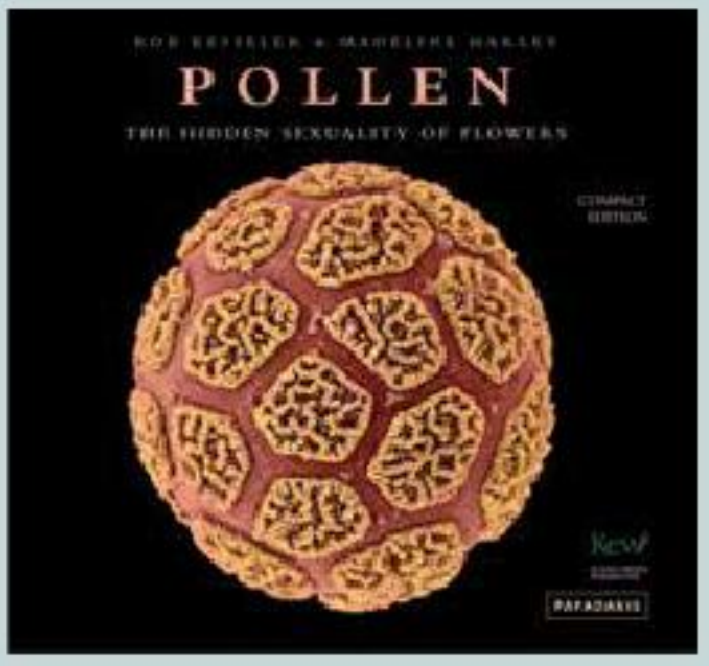
Mother of God: £12.91 from Amazon. ISBN-13: 978-0593072745. Bantam Press

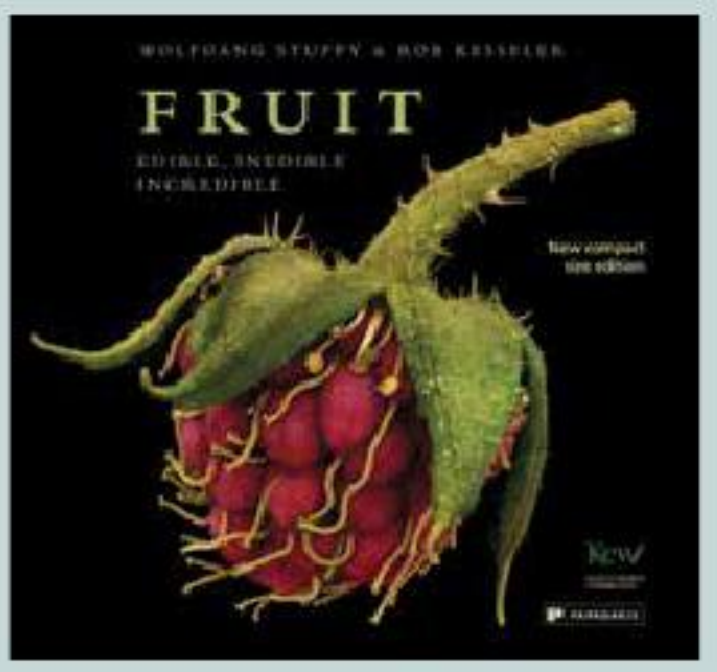
UP CLOSE & PERSONAL

Maybe the prospect of a book about seeds, pollen or fruit might not immediately have all of you searching in the bookstores - but there's something a little different about these three. They have enough information packed into their pages to be educational textbooks, but they're far from it. The in depth information is brought to life through the weirdest and most beautiful images of seeds, pollen and fruit you might have seen in a long time. "So, while we ponder technical questions of scale, form, structure, variety, mechanisms and purpose, let's not forget that we are also leafing through a body of artwork that conjures up worlds within worlds, where beauty lurks within imperfection and where perefection can still dramatically reappear out of order."

Seeds: £13.60 from Amazon. ISBN-13: 978-1906506520. Pollen: £20 from Amazon. ISBN-13: 978-1906506513. Fruit: £35 from Amazon. ISBN-13: 978-1906506421.







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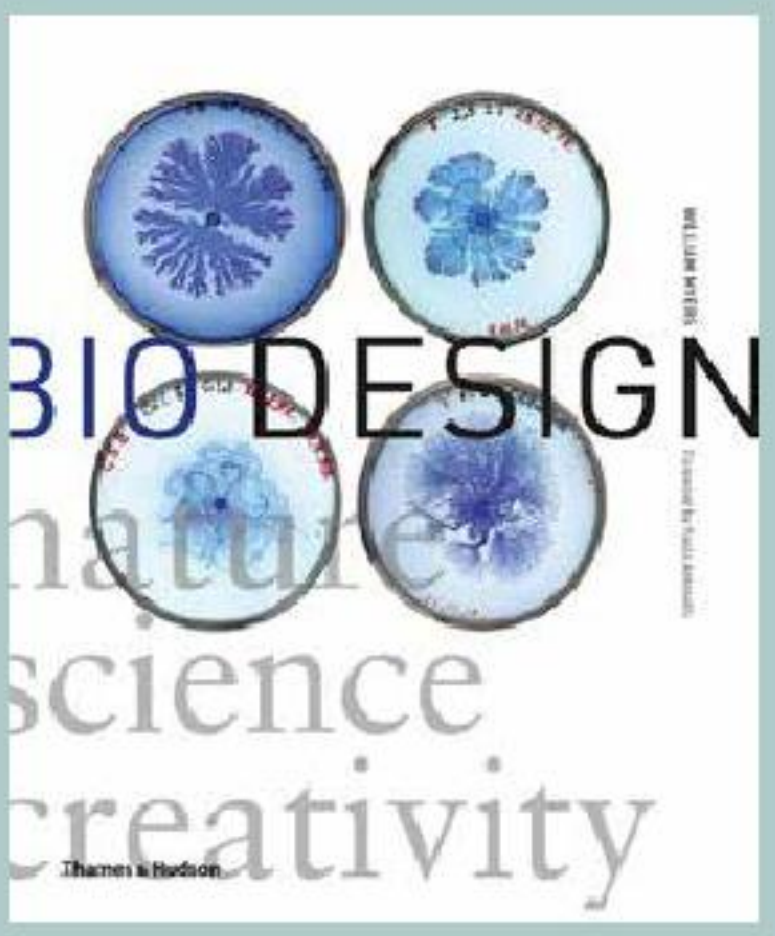

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info@biospheremagazine.co.uk

Weird Inventions

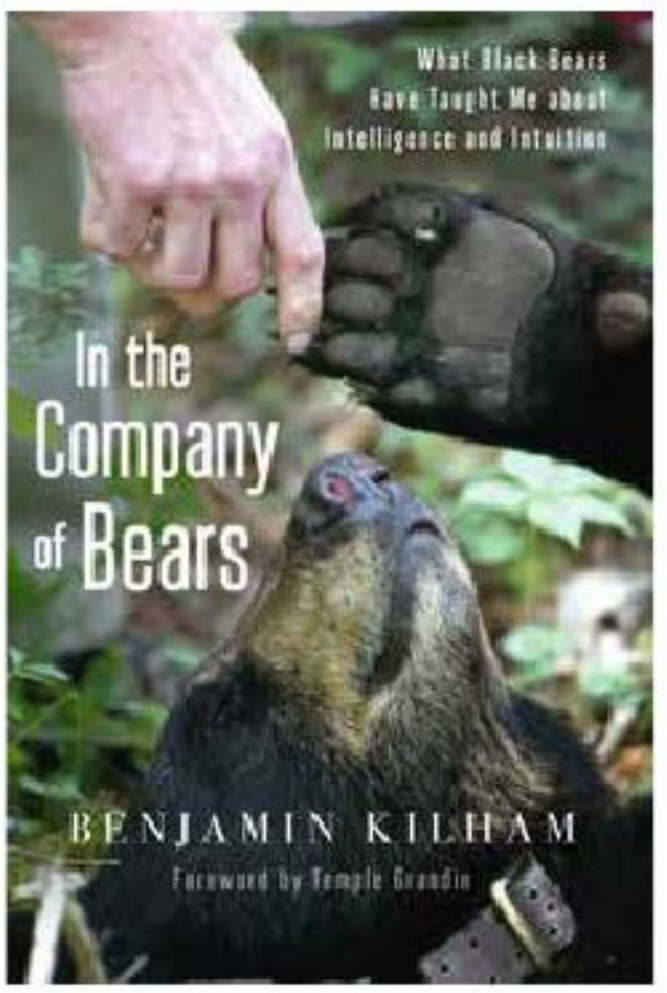
This book is an exploration of the insanely weird and the absolutely fascinating. I found myself jumping between two main questions; "Is that even possible?" and "Why would you even...?"

Did you know bioluminescent water pistols have been invented? Designed on living sea organisms but using mechanical processes, they shoot illuminated fountains of water that look like you're spraying fireworks.

Did you know mushrooms could be the answer to finding a sustainable alternative to plastics? Or that you could feed fungi those plastics, and then use that fungi as a source of food?

Biosdesign is art, it's science, and it's nature both separately and all at once. It covers architecture, industry, education, fine art, engineering and bioengineering. I defy you to come away not knowing something new, or looking at nature or biology in a slightly different way.

Biodesign: £16.89 from Amazon. ISBN-13: 978-0500291504. Thames & Hudson Publishing.



Black bears: Their secret lives

What better way to learn than through eloquent narrative and obvious passion? Reading a textbook or a hundred papers on black bears might be the more academic thing to do, but I'd be willing to bet you'd retain more valuable information by immersing yourself in this book by Benjamin Kilham.

Benjamin has hand reared over a dozen black bears, he became their mother - feeding them, protecting them, and showing them the wild again. The bears were released and had families of their own, but maintained their relationship with their adoptive mother. Benjamin was therefore able to gain an amazing insight into the lives and behaviours of black bears, and here he tells all. Perhaps the personification of the bears that Benjamin uses isn't strictly scientific, but this seems a deliberate defiance of those scientific rules. He will not let us be so self absorbed that we will continue to believe so many of our 'intelligent' behaviours are confined to our own species - not in the face of a lifetime of interactions, companionships, and evidence.

In the Company of Bears: £8.39 from Amazon. ISBN-13: 978-1603585873. Chelsea Green Publishing

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